Chapter 10

Log Periodic Arrays

A log periodic antenna is a system of driven elements, designed to be operated over a wide range of frequencies. Its advantage is that it exhibits essentially constant characteristics over the frequency range—the same radiation resistance (and therefore the same SWR), and the same pattern characteristics (approximately the same gain and the same front-to-back ratio). Not all elements in the system are active on a single frequency of operation; the design of the array is such that the active region shifts among the elements with changes in operating frequency. R. H. DuHamel and D. E. Isbell published the first information on log periodic arrays in professional literature in the late 1950s. The first log-periodic antenna article to be published in amateur literature appeared in November 1959 *QST*, and was written by Carl T. Milner, W1FVY. (See the Bibliography at the end of this chapter.)

Several varieties of log periodic antenna systems exist, such as the zig-zag, planar, trapezoidal, slot, V, and the dipole. The type favored by amateurs is the log-periodic dipole array, often abbreviated LPDA. The LPDA, shown in **Fig 1**, was invented by D. E. Isbell at the University of Illinois in 1958. Similar to a Yagi antenna in construction and appearance, a log-periodic dipole array may be built as a rotatable system for all the upper HF bands, such as 18 to 30 MHz. The longest element, at the rear of the array, is a half wavelength at the lower design frequency.

Depending on its design parameters, the LPDA can be operated over a range of frequencies having a ratio of 2:1 or higher. Over this range its electrical characteristics—gain, feed-point impedance, front-to-back ratio, and so forth—remain more or less constant. This is not true of any other type of antenna discussed in this book. With a Yagi or quad antenna, for example, either the gain factor or the front-to-back ratio, or both, deteriorate rapidly as the frequency of operation departs from the optimum design frequency of the array. And because those antennas are based on resonant elements, off-resonance operation introduces reactance which causes the SWR in the feeder system to increase. Even terminated antennas such as a rhombic exhibit significant changes in gain over a 2:1 frequency ratio.

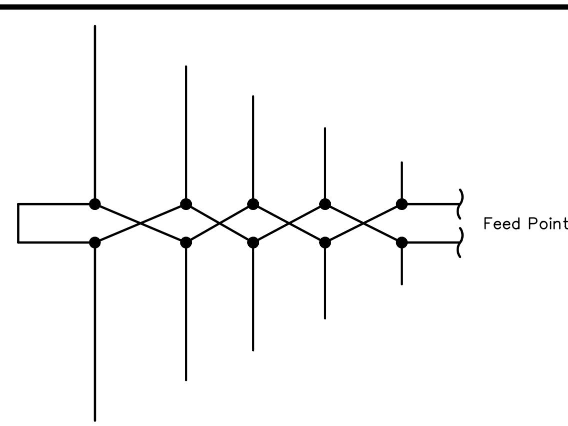

Fig 1—A log periodic dipole array. All elements are driven, as shown. The forward direction of the array as drawn here is to the right. Sometimes the elements are sloped forward, and sometimes parasitic elements are used to enhance the gain and front-to-back ratio.

As may be seen in Fig 1, the log periodic array consists of several dipole elements which are each of different lengths and different relative spacings. A distributive type of feeder system is used to excite the individual elements. The element lengths and relative spacings, beginning from the feed point for the array, are seen to increase smoothly in dimension, being greater for each element than for the previous element in the array. It is this feature upon which the design of the LPDA is based, and which permits changes in frequency to be made without greatly affecting the electrical operation. With changes in operating frequency, there is a smooth transition along the array of the elements which comprise the active region. The following information is based on a November 1973 *QST* article by Peter Rhodes, K4EWG.

A good LPDA may be designed for any single amateur band or for adjacent bands, HF to UHF, and can be built to meet the amateur's requirements at nominal cost: high forward gain, good front-to-back ratio, low SWR, and a boom length equivalent to a full-sized 3-element Yagi. The LPDA exhibits a relatively low SWR (usually not greater than 2:1) over a wide band of frequencies. A well-designed LPDA can yield a 1.3:1 SWR over a 1.8-to-1 frequency range with a typical gain of 7.0 dB over an isotropic radiator (dBi) assuming a lossless system. This equates to approximately 4.9 dB gain over a half-wave dipole (dBd).

BASIC THEORY

The LPDA is frequency independent in that the electrical properties vary periodically with the logarithm of the frequency. As the frequency, f1, is shifted to another frequency, f2, within the passband of the antenna, the relationship is

$$f2 = f1/\tau \qquad \text{(Eq 1)}$$

where

τ = a design parameter, a constant; $\tau < 1.0$. Also,
$f3 = f1/\tau^2$
$f4 = f1/\tau^3$
.
.
.
$f_n = f1/\tau^{n-1}$
$n = 1, 2, 3, \ldots n$
f1 = lowest frequency
f_n = highest frequency

The design parameter τ is a geometric constant near 1.0 that is used to determine the element lengths, ℓ, and element spacings, d, as shown in **Fig 2**. That is,

$\ell 2 = \tau \ell 1$
$\ell 3 = \tau \ell 2$
.
.
.

$$\ell_n = \tau \ell_{(n-1)} \qquad \text{(Eq 2)}$$

where

ℓ_n = shortest element length, and
$d_{23} = \tau d_{12}$
$d_{34} = \tau d_{23}$
.
.
.

$$d_{n-1,n} = \tau d_{n-2,n-1} \qquad \text{(Eq 3)}$$

where d_{23} = spacing between elements 2 and 3.

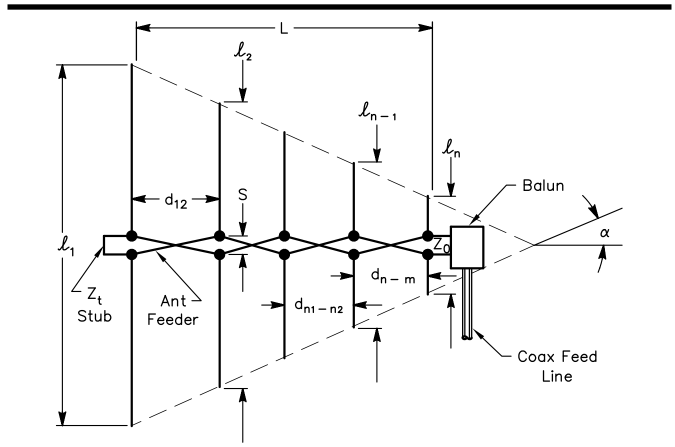

Fig 2—Schematic diagram of log periodic dipole array, with some of the design parameters indicated. Design factors are:

$$\tau = \frac{\ell_n}{\ell_{n-1}} = \frac{d_{n,n-1}}{d_{n-2,n-1}}$$

$$\sigma = \frac{d_{n,n-1}}{2\ell_{n-1}}$$

where
ℓ = element length
d = element spacing
τ = design constant
σ = relative spacing constant
S = feeder spacing
Z_0 = characteristic impedance of antenna feeder

Each element is driven with a phase shift of 180° by switching or alternating element connections, as shown in Fig 2. At a median frequency the dipoles near the input, being nearly out of phase and close together, nearly cancel each other's radiation. As the element spacing, d, increases along the array, there comes a point where the phase delay in the transmission line combined with the 180° switch gives a total of 360°. This puts the radiated fields from the two dipoles in phase in a direction toward the apex. Hence, a lobe coming off the apex results.

This phase relationship exists in a set of dipoles known as the "active region." If we assume that an LPDA is designed for a given frequency range, then that design must include an active region of dipoles for the highest and lowest design frequency. It has a bandwidth which we shall call B_{ar}, bandwidth of the active region.

Assume for the moment that we have a 12-element LPDA. Currents flowing in the elements are both real and imaginary, the real current flowing in the resistive component of the impedance of a particular dipole, and the imaginary flowing in the reactive component. Assume that the operating frequency is such that element number 6 is near to being half-wave resonant. The imaginary parts of the currents in shorter elements 7 to 12 are capacitive, while those in longer elements 1 to 5 are inductive. The capacitive current components in shorter elements 9 and 10 exceed the conductive components; hence, these elements receive little power from the feeder and act as parasitic directors. The inductive current components in longer elements 4 and 5 are dominant and they act as parasitic reflectors. Elements 6, 7 and 8 receive most of their power from the feeder and act as driven elements. The amplitudes of the currents in the remaining elements are small and they may be ignored as primary contributors to the radiation field. Hence, we have a generalized Yagi array with seven elements comprising the active region. It should be noted that this active region is for a specific set of design parameters ($\tau = 0.93$, $\sigma = 0.175$). The number of elements making up the active region varies with τ and σ. Adding more elements on either side of the active region cannot significantly modify the circuit or field properties of the array.

This active region determines the basic design parameters for the array, and sets the bandwidth for the structure, B_s. That is, for a design-frequency coverage of bandwidth B, there exists an associated bandwidth of the active region such that

$$B_s = B \times B_{ar} \quad \text{(Eq 4)}$$

where

$$B = \text{operating bandwidth} = \frac{f_n}{f1} \quad \text{(Eq 5)}$$

f1 = lowest frequency, MHz

f_n = highest frequency, MHz

B_{ar} varies with τ and α as shown in **Fig 3**. Element lengths which fall outside B_{ar} play an insignifi-

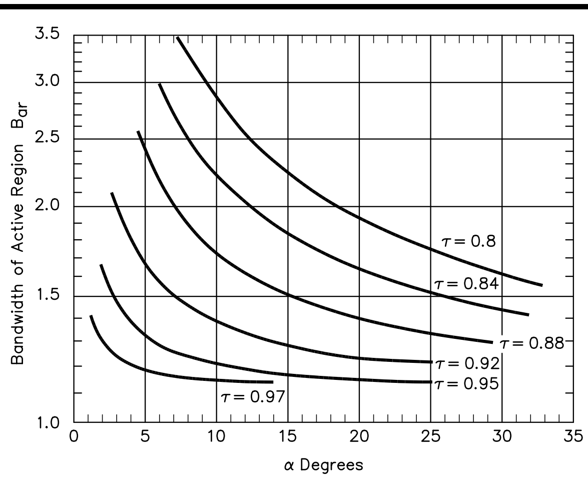

Fig 3—Design graph showing the relationships among α, τ and the bandwidth of the active region, B_{ar}. (After Carrel)

cant role in the operation of the array. The gain of an LPDA is directly related to its directivity, and is determined by the design parameter τ and the relative element spacing constant σ. **Fig 4** shows the relationship between these parameters. For each value of τ in the range $0.8 \le \tau < 1.0$, there exists an optimum value for σ we shall call σ_{opt}, for which the gain is maximum. However, the increase in gain obtained by using σ_{opt} and τ near 1.0 (such as $\tau = 0.98$) is only 3 dB when compared with the minimum σ ($sigma_{min} = 0.05$) and $\tau = 0.98$, as may be seen in Fig 4.

An increase in τ means more elements, and optimum σ means a long boom. A high-gain (6.8 dBi) LPDA can be designed in the HF region with $\tau = 0.9$ and $\sigma = 0.05$. The relationship of τ, σ and α is as follows:

$$\sigma = (1/4)(1 - \tau) \cot \alpha \qquad \text{(Eq 6)}$$

where

α = 1/2 the apex angle
τ = design constant
σ = relative spacing constant

$$\text{Also } \sigma = \frac{d_{n,n-1}}{2\ell_{n-1}} \qquad \text{(Eq 7)}$$

$$\sigma_{opt} = 0.243\tau - 0.051 \qquad \text{(Eq 8)}$$

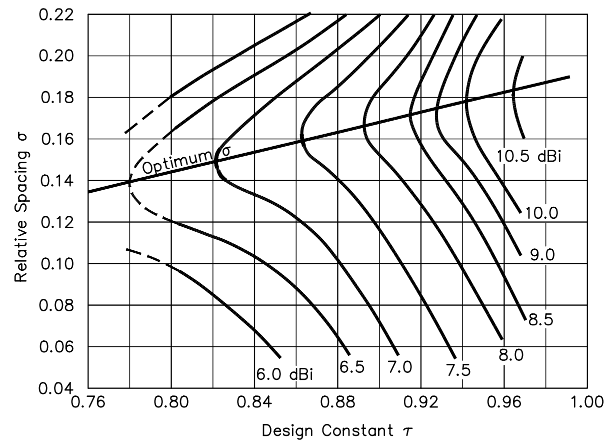

Fig 4—LPDA directivity (gain over isotropic, assuming no losses) as a function of τ and σ, for a length to diameter ratio of 125 for the element at the feed point. For each doubling of ℓ/diam, the directivity decreases by about 0.2 dB for ℓ/diam values in the range 50 to 10000. Gain relative to a dipole may be obtained by subtracting 2.14 dB from the values indicated. (After Carrel, followed up by Butson and Thompson)

FEEDING THE LPDA

The method of feeding the antenna is rather simple. As shown in Fig 2, a balanced feeder is required for each element, and all adjacent elements are fed with a 180° phase shift by alternating element connections. In this section the term *antenna feeder* is defined as that line which connects each adjacent element. The *feed line* is that line between antenna and transmitter.

The input resistance of the LPDA, R_0, varies with frequency, exhibiting a periodic characteristic. The range of the feed-point resistance depends primarily on Z_0, the characteristic impedance of the antenna feeder. R_0 may therefore be selected to some degree by choosing Z_0, that is, by choosing the conductor size and the spacing of the antenna feeder conductors. Other factors that affect R_0 are the average characteristic impedance of a dipole, Z_{av}, and the mean spacing factor, σ'. As an approximation (to within about 10%), the relationship is as follows:

$$R_0 = \frac{Z_0}{\sqrt{1 + \frac{Z_0}{4\sigma' Z_{av}}}} \qquad \text{(Eq 9)}$$

where

R_0 = mean radiation resistance level of the LPDA input impedance
Z_0 = characteristic impedance of antenna feeder

Z_{av} = average characteristic impedance of a dipole

$$= 120\left[\ln\left(\frac{\ell_n}{d_n}\right) - 2.25\right] \quad \text{(Eq 10)}$$

$\ell_n/diam_n$ = length to diameter ratio of *n*th element

$$\sigma' = \text{mean spacing factor} = \frac{\sigma}{\sqrt{\tau}} \quad \text{(Eq 11)}$$

The mean spacing factor, σ', is a function of τ and α (Eqs 6 and 11). For a fixed value of Z_0, R_0 decreases with increasing τ and increasing α.

If all element diameters are identical, then the element ℓ/diam ratios will increase along the array. Ideally the ratios should remain constant, but from a practical standpoint the SWR performance of a single-band LPDA will not be noticeably degraded if all elements are of the same diameter. But to minimize SWR variations for multiband designs, the LPDA may be constructed with progressively increasing element diameters from the front to the back of the array. This approach also offers structural advantages for self-supporting elements, as larger conductors will be in place for the longer elements.

The standing-wave ratio varies periodically with frequency. The mean value of SWR, with respect to R_0, has a minimum of about 1.1:1 at σ_{opt} (Eq 8), and rises to a value of 1.8:1 at $\sigma = 0.05$. In other words, the periodic SWR variation (with frequency changes) swings over a wider range of SWR values with lower values of σ. These SWR ranges are acceptable when using standard 52 and 72-Ω coax for the feed line. However, a 1:1 SWR match can be obtained at the transmitter end by using a coax-to-coax Transmatch. A Transmatch enables the transmitter low-pass filter to see a 52-Ω load on each frequency within the array passband. The Transmatch also eliminates possible harmonic radiation caused by the frequency-independent nature of the array.

R_0 should be chosen for the intended balun and feed-line characteristics. For HF arrays, a value of 208 Ω for R_0 usually works well with a 4:1 balun and 52-Ω coax. Direct 52-Ω feed is usually not possible. (Attempts may result in smaller conductor spacing for the antenna feeder than the conductor diameter, a physical impossibility.)

For VHF and UHF designs, the antenna feeder may also serve as the boom. With this technique, element halves are supported by feeder conductors of tubing that are closely spaced. If R_0 is selected as 72 Ω, direct feed with 72-Ω cable is possible. An effective balun exists if the coax is passed through one of the feeder conductors from the rear of the array to the feed point. **Fig 5** shows such a feed-point arrangement.

If the design bandwidth of the array is fairly small (single band), another possible approach is to design the array for a 100-Ω R_0 and use a $^1/_4$-wave matching section of 72-Ω coax between the feed point and 52-Ω feed line. In any case, select the element feeder diameters based on mechanical considerations. The required feeder spacing may then be calculated.

The antenna feeder termination, Z_t, is a short circuit at a distance of $\lambda_{max}/8$ or less behind element no. 1, the longest element. In his 1961 paper on LPDAs, Dr Robert L. Carrel reported satisfactory results in some cases by using a short circuit at the terminals of element no. 1. If this is done, the shorted element acts as a passive reflector at the lowest frequencies. Some constructors indicate that Z_t may be eliminated altogether without significant effect on the results. The terminating stub impedance tends to increase the front-to-back ratio for the lowest frequencies. If used, its length may be adjusted for the best results, but in any case it should be no longer than $\lambda_{max}/8$. For HF-band operation a 6-inch shorting jumper wire may be used for Z_t.

It might also be noted that one could increase the front-to-back ratio on the lowest frequency by

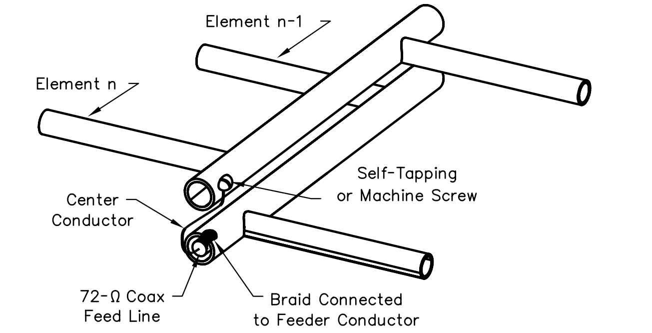

Fig 5—A method of feeding the LPDA for VHF and UHF designs.

moving the passive reflector (element no. 1) a distance of 0.15 to 0.25 λ behind element no. 2, as would be done in the case of an ordinary Yagi parasitic reflector. This of course would necessitate lengthening the boom. The front-to-back ratio increases somewhat as the frequency increases. This is because more of the shorter inside elements form the active region, and the longer elements become additional reflectors.

DESIGN PROCEDURE

The preceding section provides information on the fundamentals of a log periodic dipole array. From that discussion, some insights may be gained into the effects of changing the various design parameters. However, a thorough understanding of LPDA basic theory is not necessary in order to design your own array. A systematic step-by-step design procedure of the LPDA is presented in this section, with design examples. There are necessarily some mathematical calculations to be performed, but these may be accomplished with a 4-function electronic calculator that additionally handles square-root and logarithmic functions. The procedure that follows may be used for designing any LPDA for any desired bandwidth.

1) Decide on an operating bandwidth B, between f1, lowest frequency and f_n, highest frequency, using Eq 5.

2) Choose τ and σ to give a desired gain (Fig 4).

$0.8 \le \tau \le 0.98$

$0.05 \le \sigma \le \sigma_{opt}$

The value of σ_{opt} may be determined from Fig 4 or from Eq 8.

3) Determine the value for the cotangent of the apex half-angle α from

$$\cot \alpha = \frac{4\sigma}{1-\tau} \qquad \text{(Eq 12)}$$

Note: α, the apex half angle itself, need not be determined as a part of this design procedure, but the value for cot α is used frequently in the steps that follow.

4) Determine the bandwidth of the active region B_{ar} either from Fig 3 or from

$$B_{ar} = 1.1 + 7.7(1-\tau)^2 \cot \alpha \qquad \text{(Eq 13)}$$

5) Determine the structure (array) bandwidth B_s from Eq 4.

6) Determine the boom length L, number of elements N, and longest element length $\ell 1$.

$$L_{ft} = \left[1/4 \left(1 - \frac{1}{B_S} \right) \cot \alpha \right] \lambda_{max} \qquad \text{(Eq 14)}$$

$$N = 1 + \frac{\log B_S}{\log \frac{1}{\tau}} = 1 + \frac{\ln B_S}{\ln \frac{1}{\tau}} \qquad \text{(Eq 15)}$$

$$\ell 1_{ft} = \frac{492}{f1} \qquad \text{(Eq 16)}$$

where λ_{max} = longest free-space wavelength = 984/f1. Usually the calculated value for N will not be an integral number of elements. If the fractional value is significant, more than about 0.3, increase the value to the next higher integer. Doing this will also increase the actual value of L over that obtained from Eq 14.

Examine L, N and $\ell 1$ to determine whether or not the array size is acceptable for your needs. If the array is too large, increase f1 or decrease σ or τ and repeat steps 2 through 6. (Increasing f1 will decrease all dimensions. Decreasing σ will decrease primarily the boom length. Decreasing τ will decrease both the boom length and the number of elements.)

7) Determine the terminating stub, Z_t. (Note: For HF arrays, short out the longest element with a 6-inch jumper. For VHF and UHF arrays use:

$$Z\tau = \lambda_{max}/8 \qquad \text{(Eq 17)}$$

8) Solve for the remaining element lengths from Eq 2.

9) Determine the element spacing, d_{12} ,from

$$d_{12} = \tfrac{1}{2} (\ell 1 - \ell 2) \cot \alpha \quad \text{(Eq 18)}$$

and the remaining element-to-element spacings from Eq 3.

10) Choose R_0, the desired feed-point resistance, to give the lowest SWR for the intended balun ratio and feed-line impedance. From the following equation, determine the necessary antenna feeder impedance, Z_0, using the definitions of terms for Eq 9.

$$Z_0 = \frac{R_0^{\ 2}}{8\sigma' Z_{av}} + R_0 \sqrt{\left(\frac{R_0}{8\sigma' Z_{av}}\right)^2 + 1} \quad \text{(Eq 19)}$$

11) Once Z_0 has been determined, select a combination of conductor size and spacing to provide that impedance from

$$S = \left(\frac{\text{diam}}{2}\right) \times 10^{Z_0/276} \quad \text{(Eq 20)}$$

where

S = center-to-center distance between conductors

diam = outer diameter of conductor (in same units as S)

Z_0 = intended characteristic impedance for antenna feeder

Note: This equation assumes round feeder conductors.

If an impractical spacing results for the antenna feeder, select a different conductor diameter and repeat step 11. In severe cases it may be necessary to select a different R_0 and repeat steps 10 and 11. Once a satisfactory feeder arrangement is found, the LPDA design is completed.

Design Example—Short Four-Band Array

Suppose we wish to design a log periodic dipole array to cover the frequency range 18.06 to 29.7 MHz. Such an array will offer operation on any frequency in the 17, 15, 12 and 10-meter amateur bands. In addition, we desire for this to be a short array, constructed on a boom of no more than 10 feet in length.

To follow through this example, it is suggested that you write the parameter names and their values as they are calculated, in columns, on your worksheet. This will provide a ready reference for the values needed in subsequent calculations.

We begin the design procedure with step 1 and determine the operating bandwidth from Eq 5: f1 = 18.06, f_n = 29.7, and B = 29.7/18.06 = 1.6445. (Note: Because log periodics have reduced gain at the low-frequency end, some designers lower f1 by several percent to assure satisfactory gain at the lower operating frequencies. Increasing f_n, the design frequency at the high end, however, appears to offer no advantage other than extended frequency coverage.) Because we wish to have a compact design, we choose not to extend the lower frequency range.

Next, step 2, we examine Fig 4 and choose values for τ, σ and gain. Knowing from the basic theory section that larger values of σ call for a longer boom, we choose the not-too-large value of 0.06. Also knowing that a compact array will not exhibit high gain, we choose a modest gain, 8.0 dBi. For these values of σ and gain, Fig 4 shows the required τ to be 0.885.

From step 3 and Eq 12, we determine the value for cot α to be $4 \times 0.06/(1 - 0.885) = 2.0870$. We need not determine α, the apex half angle, but if we wish to go to the trouble we can use the relationship

$$\alpha = \text{arc cot } 2.0870 = \text{arc tan } (1/2.0870) = 25.6°$$

This means the angle at the apex of the array will be $2 \times 25.6 = 51.2°$.
From step 4 and Eq 13, we calculate the value for B_{ar} as $1.1 + 7.7(1 - 0.885)^2 \times 2.097 = 1.3125$.
Next, from step 5 and Eq 4, we determine the structure bandwidth B_s to be $1.6445 \times 1.3125 = 2.1584$.
From step 6 and the associated equations we determine the boom length, number of elements, and

longest element length.

$$L = \left[1/4\left(1 - \frac{1}{2.1584}\right) \times 2.0870\right]\frac{984}{18.06} = 15.26 \text{ ft}$$

$$N = 1 + \frac{\log 2.1584}{\log(1/0.885)} = 1 + \frac{0.3341}{0.05306} = 7.30$$

(Because a *ratio* of logarithmic values is determined here, either common or natural logarithms may be used in the equation, as long as both the numerator and the denominator are the same type; the results are identical.)

$\ell 1 = 492/18.06 = 27.243$ ft

The 15.26-foot boom length is greater than the 10-foot limit we desired, so some change in the design is necessary. The 7.30 elements should be increased to 8 elements if we chose to proceed with this design, adding still more to the boom length. The longest element length is a function solely of the lowest operating frequency, so we do not wish to change that.

Decreasing either σ or τ will yield a shorter boom. Because σ is already close to the minimum value of 0.05, we decide to retain the value of 0.06 and decrease the value of τ. Let's try τ = 0.8. Rep¼ ng steps 2 through 6 with these values, we calculate the following.

Gain = 5.3 dBi? (outside curves of graph)
cot α = 1.2000
B_{ar} = 1.4696
B_s = 2.4168
L = 9.58 ft
N = 4.95
$\ell 1$ = 27.243 ft

These results nicely meet our requirement for a boom length not to exceed 10 feet. The 4.95 elements obviously must be increased to 5. The 5.3 dBi gain (3.2 dBd) is nothing spectacular, but the array should have a reasonable front-to-back ratio. For four-band coverage with a short boom, we decide this gain and array dimensions are acceptable, and we choose to go ahead with the design. The variables summarized on our worksheet now should be those shown in the first portion of **Table 1**.

Continuing at step 7, we make plans to use a 6-inch shorted jumper for the terminating stub, Z_t.

From step 8 and Eq 2 we determine the element lengths:

$$\ell 2 = \tau \ell 1 = 0.8 \times 27.243 = 21.794 \text{ ft}$$
$$\ell 3 = 0.8 \times 21.794 = 17.436 \text{ ft}$$
$$\ell 4 = 0.8 \times 17.436 = 13.948 \text{ ft}$$
$$\ell 5 = 0.8 \times 13.948 = 11.159 \text{ ft}$$

From step 9 and Eq 18 we calculate the element spacing d_{12} as ½ (27.243 – 21.794) × 1.2 = 3.269 ft. Then from Eq 3 we determine the remaining element spacings:

$$d_{23} = 0.8 \times 3.269 = 2.616 \text{ ft}$$
$$d_{34} = 0.8 \times 2.616 = 2.092 \text{ ft}$$
$$d_{45} = 0.8 \times 2.092 = 1.674 \text{ ft}$$

This completes the calculations of the array dimensions. The work remaining is to design the

Table 1
Design Parameters for the 4-Band LPDA

f1 = 18.06 MHz	Element lengths:
f_n = 29.7 MHz	$\ell 1$ = 27.243 ft
B = 1.6445	$\ell 2$ = 21.794 ft
τ = 0.8	$\ell 3$ = 17.436 ft
σ = 0.06	$\ell 4$ = 13.948 ft
Gain = 5.3 dBi = 3.2 dBd	$\ell 5$ = 11.159 ft
cot α = 1.2000	Element spacings:
B_{ar} = 1.4696	d_{12} = 3.269 ft
B_s = 2.4168	d_{23} = 2.616 ft
L = 9.58 ft	d_{34} = 2.092 ft
N = 4.95 elements (increase to 5)	d_{45} = 1.674 ft
	Element diameters:
Z_t = 6-in. shorted jumper	$diam_5$ = ½ in.;
R_o = 208 Ω	$\ell 5/diam_5$ = 267.8
Z_{av} = 400.8 Ω	$diam_4$ = ⅝ in.;
σ′ = 0.06708	$\ell 4/diam_4$ = 267.8
Z_0 = 490.5 Ω	$diam_3$ = ¾ in.;
Antenna feeder:	$\ell 3/diam_3$ = 279.0
#12 wire spaced 2.4 in.	$diam_2$ = 1 in.;
Balun: 4 to 1	$\ell 2/diam_2$ = 261.5
Feed line: 52-Ω coax	$diam_1$ = 1¼ in.;
	$\ell 1/diam_1$ = 261.5

antenna feeder. From step 10, we wish to feed the LPDA with 52-Ω line and a 4:1 balun, so we select R_0 as 4 × 52 = 208 Ω.

Before we calculate Z_0 from Eq 19 we must first determine Z_{av} from Eq 10. At this point we must assign a diameter to element no. 5. We wish to make the array rotatable with self-supporting elements, so we shall use aluminum tubing for all elements. For element no. 5, the shortest element, we plan to use tubing of 1/2-inch OD. We calculate the length to diameter ratio by first converting the length to inches:

$$\ell 5/\text{diam}_5 = 11.159 \times 12/0.5 = 267.8$$

At this point in the design process we may also assign diameters to the other elements. To maintain an essentially constant ℓ/diam ratio along the array, we shall use larger tubing for the longer elements. (From a practical standpoint for large values of τ, 2 or 3 adjacent elements could have the same diameter. For a single-band design, they could all have the same diameter.) From data in Chapter 21 we see that, above 1/2 inch, aluminum tubing is available in diameter steps of 1/8 inch. We assign additional element diameters and determine ℓ/diam ratios as follows:

diam_4 = 5/8 in.; $\ell 4/\text{diam}_4 = 13.948 \times 12/0.625 = 267.8$
diam_3 = 3/4 in.; $\ell 3/\text{diam}_3 = 17.436 \times 12/0.75 = 279.0$
diam_2 = 1 in.; $\ell 2/\text{diam}_2 = 21.794 \times 12/1 = 261.5$
diam_1 = 1 1/4 in.; $\ell 1/\text{diam}_1 = 27.243 \times 12/1.25 = 261.5$

Tapered elements with telescoping tubing at the ends may certainly be used. From a matching standpoint, the difference from cylindrical elements is of minor consequence. (Performance at the low-frequency end may suffer slightly, as tapered elements are electrically shorter than their cylindrical counterparts having a diameter equal to the average of the tapered sections. See Chapter 2.)

In Eq 10 the required length to diameter ratio is that for element no. 5, or 267.8. Now we may determine Z_{av} as

$$Z_{av} = 120\,[\ln 267.8 - 2.25] = 120\,[5.590 - 2.25] = 400.8$$

Additionally, before solving for Z_0 from Eq 19, we must determine σ′ from Eq 11.

$$\sigma' = \frac{0.06}{\sqrt{0.8}} = 0.06708$$

And now we use Eq 19 to calculate Z_0.

$$Z_0 = \frac{208^2}{8 \times 0.06708 \times 400.8} + 208\sqrt{\left(\frac{208}{8 \times 0.06708 \times 400.8}\right)^2 + 1}$$
$$= 201.1 + 208 \times \sqrt{1.935} = 490.5\ \Omega$$

From step 11, we are to determine the conductor size and spacing for a Z_0 of 490.5 Ω for the antenna feeder. We elect to use #12 wire, and from data in Chapter 20 learn that its diameter is 80.8 mils or 0.0808 inch. We determine the spacing from Eq 20 as

$$S = \left(\frac{0.0808}{2}\right) \times 10^{490.5/276} = \frac{0.0808}{2} \times 10^{1.777}$$
$$= \frac{0.0808}{2} \times 59.865 = 2.42 \text{ in.}$$

An open-wire line of #12 wire with 2.4-inch spacers may be used for the feeder. This completes the design of the four-band LPDA. The design data are summarized in Table 1.

Wire Log-Periodic Dipole Arrays for 3.5 or 7 MHz

These log-periodic dipole arrays are simple and easy to build. They are designed to have reasonable gain, be inexpensive and lightweight, and they may be assembled with stock items found in large hardware stores. They are also strong—they can withstand a hurricane! These antennas were first described by John J. Uhl, KV5E, in *QST* for August 1986. **Fig 6** shows one method of installation. You can use the information presented here as a guide and point of reference for building similar LPDAs.

If space is available, the antennas can be "rotated" or repositioned in azimuth after they are completed. A 75-foot tower and a clear turning radius of 120 feet around the base of the tower are needed. The task is simplified if only three anchor points are used, instead of the five shown in Fig 6. Omit the two anchor points on the forward element, and extend the two nylon strings used for element stays all the way to the forward stay line.

DESIGN OF THE LOG-PERIODIC DIPOLE ARRAYS

Design constants for the two arrays are listed in **Tables 2** and **3**. The preceding sections of this chapter contain a more precise design procedure than that presented in earlier editions of *The ARRL Antenna Book*, resulting in slightly different feeder design values than those appearing in *QST*.

The process for determining the values in Tables 2 and 3 is identical to that given in the preceding example. The primary differences are the narrower frequency ranges and the use of wire, rather than tubing, for the elements. As additional design examples for the LPDA, you may wish to work through the step-by-step procedure and check your results against the values in Tables 2 and 3.

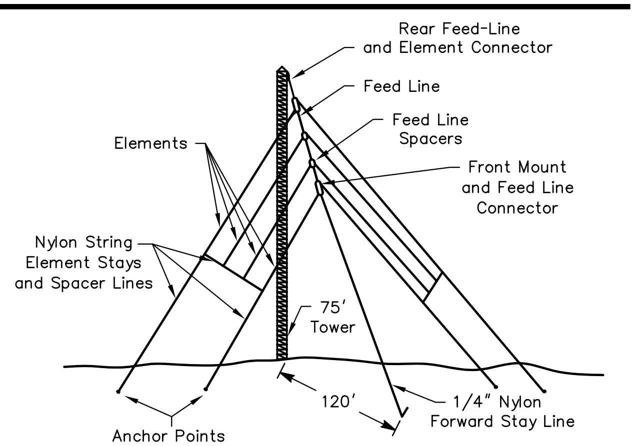

Fig 6—Typical 4-element log-periodic dipole array erected on a tower.

Table 2
Design Parameters for the 3.5-MHz Single-Band LPDA

f1 = 3.3 MHz
f_n = 4.1 MHz
B = 1.2424
τ = 0.845
σ = 0.06
Gain = 5.9 dBi = 3.8 dBd
cot α = 1.5484
B_{ar} = 1.3864
B_s = 1.7225
L = 48.42 ft
N = 4.23 elements (decrease to 4)
Z_t = 6-in. shorted jumper
R_o = 208 Ω
Z_{av} = 897.8 Ω
σ' = 0.06527
Z_0 = 319.8 Ω
Antenna feeder:
#12 wire spaced 0.58 in.
Balun: 4 to 1
Feed line: 52-Ω coax

Element lengths:
$\ell 1$ = 149.091 ft
$\ell 2$ = 125.982 ft
$\ell 3$ = 106.455 ft
$\ell 4$ = 89.954 ft
Element spacings:
d_{12} = 17.891 ft
d_{23} = 15.118 ft
d_{34} = 12.775 ft
Element diameters:
All = 0.0641 in.
ℓ/diam ratios:
$\ell 4/diam_4$ = 16840
$\ell 3/diam_3$ = 19929
$\ell 2/diam_2$ = 23585
$\ell 1/diam_1$ = 27911

Table 3
Design Parameters for the 7-MHz Single-Band LPDA

f1 = 6.9 MHz
f_n = 7.5 MHz
B = 1.0870
τ = 0.845
σ = 0.06
Gain = 5.9 dBi = 3.8 dBd
cot α = 1.5484
B_{ar} = 1.3864
B_s = 1.5070
L = 18.57 ft
N = 3.44 elements (increase to 4)
Z_t = 6-in. shorted jumper
R_o = 208 Ω
Z_{av} = 809.3 Ω
σ' = 0.06527
Z_0 = 334.2 Ω
Antenna feeder:
#12 wire spaced 0.66 in.
Balun: 4 to 1
Feed line: 52-Ω coax

Element lengths:
$\ell 1$ = 71.304 ft
$\ell 2$ = 60.252 ft
$\ell 3$ = 50.913 ft
$\ell 4$ = 43.022 ft
Element spacings:
d_{12} = 8.557 ft
d_{23} = 7.230 ft
d_{34} = 6.110 ft
Element diameters:
All = 0.0641 in.
ℓ/diam ratios:
$\ell 4/diam_4$ = 8054
$\ell 3/diam_3$ = 9531
$\ell 2/diam_2$ = 11280
$\ell 1/diam_1$ = 13349

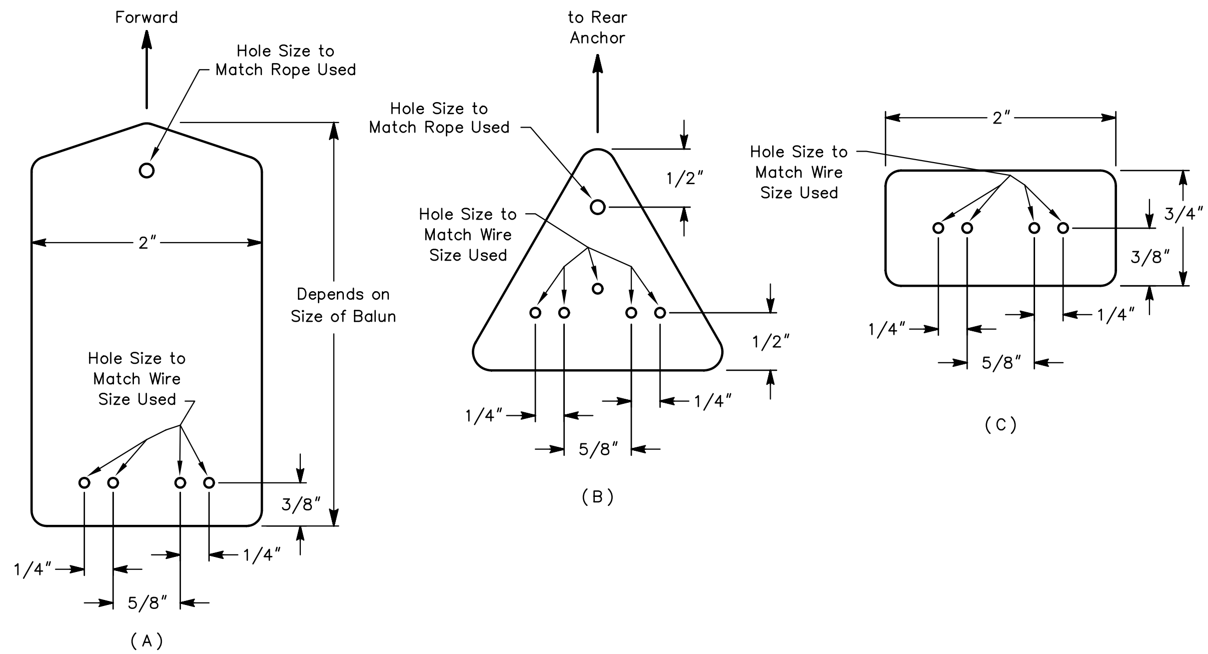

Fig 7—Pieces to be fabricated for the LPDA. At A, the forward connector, made from 1/2-in. Lexan. At B, the rear connector, also made from 1/2-in. Lexan. At C is the pattern for the feed-line spacers, made from 1/4-in. Plexiglas. Two of these spacers are required.

From the design procedure, the feeder spacings for the two arrays are slightly different, 0.58 inch for the 3.5-MHz array and 0.66 inch for the 7-MHz version. As a compromise toward the use of common spacers for both bands, a spacing of 5/8 inch is quite satisfactory. Surprisingly, the feeder spacing is not at all critical here from a matching standpoint, as may be verified from Z_0 = 276 log (2S/diam) and from Eq 9. Increasing the spacing to as much as 3/4 inch results in an R_0 SWR of less than 1.1 to 1 on both bands.

Constructing the Arrays

The construction techniques are the same for both the 3.5 and the 7-MHz versions of the array. Once the designs are completed, the next step is to fabricate the fittings; see **Fig 7** for details. Cut the wire elements and feed lines to the proper sizes and mark them for identification. After the wires are cut and placed aside, it will be difficult to remember which is which unless they are marked. When you have finished fabricating the connectors and cutting all of the wires, the antenna can be assembled. Use your ingenuity when building one of these antennas; it isn't necessary to duplicate these LPDAs exactly.

The elements are made of standard #14 stranded copper wire. The two parallel feed lines are made of #12 solid copper-coated steel wire, such as Copperweld. This will not stretch when placed under tension. The front and rear connectors are cut from 1/2-inch thick Lexan sheeting, and the feed-line spacers from 1/4-inch Plexiglas sheeting.

Study the drawings carefully and be familiar with the way the wire elements are connected to the two feed lines, through the front, rear and spacer connectors. Details are sketched in **Figs 8 and 9**. Connections made this way prevent the wire from breaking. All of the rope, string and connectors must be made of materials that can withstand the effects of tension and weathering. Use nylon rope and strings, the type that yachtsmen use. Fig 6 shows the front stay rope coming down to ground level at a point 120 feet from the base of a 75-foot tower. It may not be possible to do this in all cases. An alternative installation technique is to put a pulley 40 feet up in a tree and run the front stay rope through the pulley and down to ground level at the base of the tree. The front stay rope will have to be tightened with a block and tackle at ground level.

Putting an LPDA together is not difficult if it is assembled in an orderly manner. It is easier to connect the elements to the feeder lines when the feed-line assembly is stretched between two points. Use the tower and a block and tackle. Attaching the rear connector to the tower and assembling the LPDA at the base of the tower makes raising the antenna into place a much simpler task. Tie the rear connector securely to the base of the tower and attach the two feeder lines to it. Then thread the two feed-line spacers onto the feed line. The spacers will be loose at this time, but will be positioned properly when the elements are connected. Now connect the front connector to the feed lines. A word of caution: Measure accurately and carefully! Double-check all measurements before you make permanent connections.

Connect the elements to the feeder lines through their respective plastic connectors, beginning with element 1, then element 2, and so on. Keep all of the element wires securely coiled. If they unravel, you will have a tangled mess of kinked wire. Check that the element-to-feeder connections have been made properly. (See Figs 8 and 9.) Once you have completed all of the element connections, attach the 4:1 balun to the underside of the front connector. Connect the feeder lines and the coaxial cable to the balun.

You will need a separate piece of rope and a pulley to raise the completed LPDA into position. First secure the eight element ends with nylon string, referring to Figs 6 and 8. The string must be long enough to reach the tie-down points. Connect the front stay rope to the front connector, and the com-

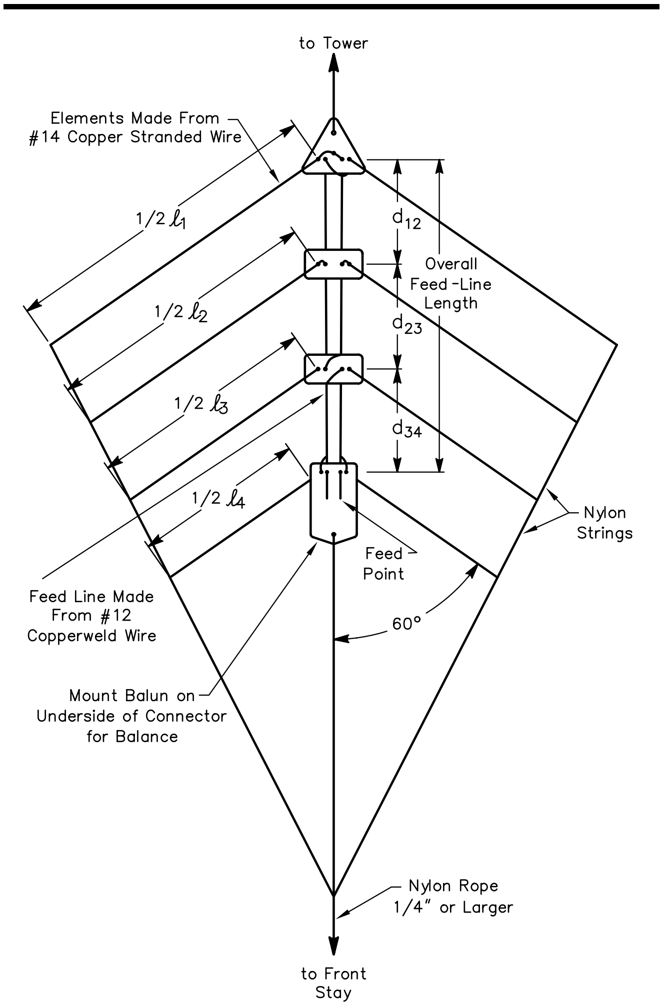

Fig 8—Typical layout for the LPDA. Use a 4:1 balun at the point indicated. See Tables 2 and 3 for dimensions.

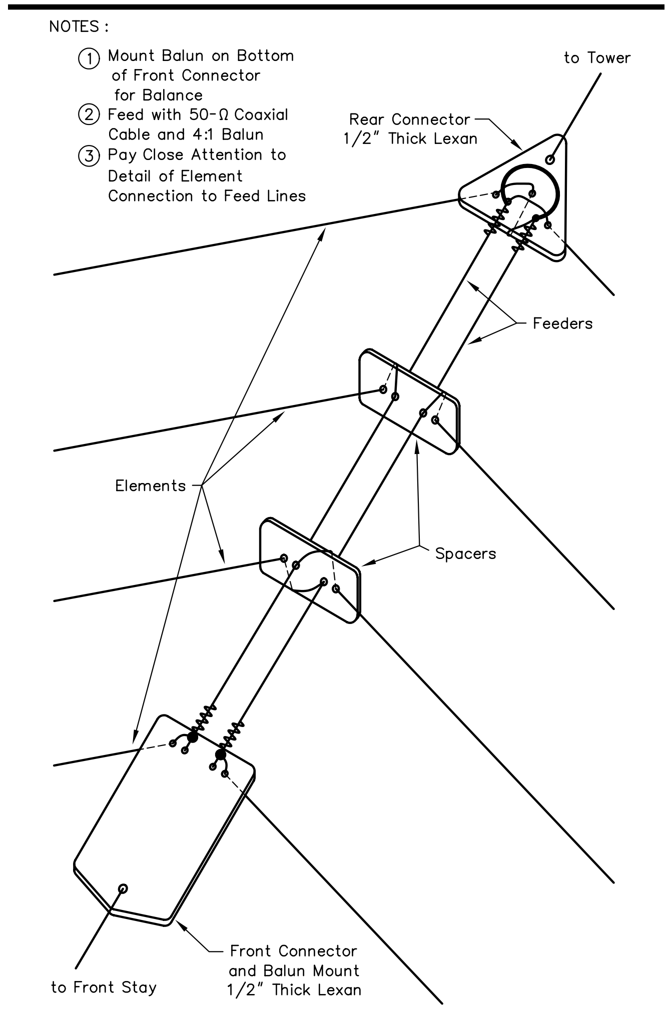

Fig 9—Details of electrical and mechanical connections of the elements to the feed line. Knots in the nylon stay lines are not shown.

pleted LPDA is now ready to be raised into position. While raising the antenna, uncoil the element wires to prevent their getting away and tangling up into a mess. Use care! Raise the rear connector to the proper height and attach it securely to the tower, then pull the front stay rope tight and secure it. Move the elements so they form a 60-degree angle with the feed lines, in the direction of the front, and space them properly relative to one another. By adjusting the end positions of the elements as you walk back and forth, you will be able to align all the elements properly. Now it is time to hook your rig to the system and make some contacts.

Performance

The reports received from these LPDAs were compared with an inverted-V dipole. All of the antennas are fixed; the LPDAs radiate to the northeast, and the dipole to the northeast and southwest. The apex of the dipole is at 70 feet, and the 40 and 80-meter LPDAs are at 60 and 50 feet, respectively. The gain of the LPDAs is several dB over the dipole. This was apparent from many of the reports received. During pileups, it was possible to break in with a few tries on the LPDAs, yet it was impossible to break in the same pileups using the dipole.

During the CQ WW DX Contest some *big* pileups were broken after a few calls with the LPDAs. Switching to the dipole, it was found impossible to break in after many, many calls. Then, after switching back to the LPDA, it was easy to break into the same pileup and make the contact.

Think of the possibilities that these wire LPDA systems offer hams worldwide. They are easy to design and to construct, real advantages in countries where commercially built antennas and parts are not available at reasonable cost. The wire needed can be obtained in all parts of the world, and cost of construction is low! If damaged, the LPDAs can be repaired easily with pliers and solder. For those who travel on DXpeditions where space and weight are large considerations, LPDAs are lightweight but sturdy, and they perform well.

5-Band Log Periodic Dipole Array

A rotatable log periodic array designed to cover the frequency range from 13 to 30 MHz is pictured in **Fig 10**. This is a large array having a gain of 6.7 dBi or 4.6 dBd (approximately the same gain one would expect with a full-size two-element Yagi array). This antenna system was originally described by Peter D. Rhodes, WA4JVE, in November 1973 *QST*. The radiation pattern, measured at 14 MHz, is shown in **Fig 11**.

The characteristics of the array are:

1) Half-power beamwidth, 43° (14 MHz)

2) Design parameter $\tau = 0.9$

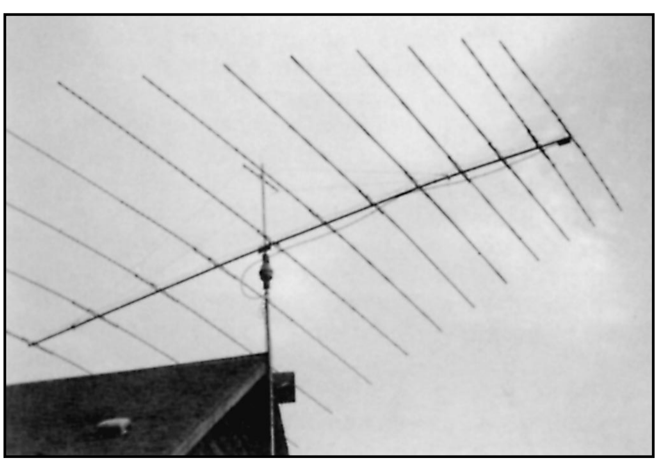

Fig 10—The 13-30 MHz log periodic dipole array.

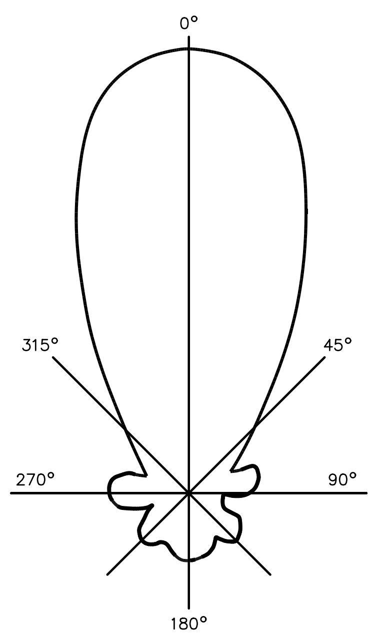

Fig 11—Measured radiation pattern of the 13-30 MHz LPDA at 14 MHz. The front-to-back ratio is 14.4 dB at 14 MHz, and increases to 21 dB at 28 MHz.

3) Relative element spacing constant σ = 0.05
4) Boom length, L = 26 ft
5) Longest element $\ell 1$ = 37 ft 10 in. (a tabulation of element lengths and spacings is given in Table 4)
6) Total weight, 116 pounds
7) Wind-load area, 10.7 sq ft
8) Required input impedance (mean resistance), R_0 = 72 Ω, Z_t = 6-inch jumper #18 wire
9) Average characteristic dipole impedance, Z_{av}: 337.8 Ω
10) Impedance of the feeder, Z_0: 117.1 Ω
11) Feeder: #12 wire, close spaced
12) With a 1:1 toroid balun at the input terminals and a 72- Ω coax feed line, the maximum SWR is 1.4:1.

The mechanical assembly uses materials readily available from most local hardware stores or aluminum supply houses. The materials needed are given in **Table 5**. In the construction diagram, **Fig 12**, the materials are referenced by their respective material list number. The photograph shows the overall construction, and the drawings show the details. **Table 6** gives the required tubing lengths to construct the elements.

Table 4
13-30 MHz Array Dimensions, Feet

El. No.	*Length*	*$d_{n-1,n}$(spacing)*	*Nearest Resonant*
1	37′ 10.2″	—	
2	34′ 0.7″	3′ 9.4″ = d_{12}	14 MHz
3	30′ 7.9″	3′ 4.9″ = d_{23}	
4	27′ 7.1″	3′ 0.8″ = d_{34}	
5	24′ 10.0″	2′ 9.1″ = d_{45}	18 MHz
6	22′ 4.2″	2′ 5.8″ = d_{56}	21 MHz
7	20′ 1.4″	2′ 2.8″ = d_{67}	
8	18′ 1.2″	2′ 0.1″ = d_{78}	24.9 MHz
9	16′ 3.5″	1′ 9.7″ = d_{89}	28 MHz
10	14′ 7.9″	1′ 7.5″ = $d_{9,10}$	
11	13′ 2.4″	1′ 5.6″ = $d_{10,11}$	
12	11′ 10.5″	1′ 3.8″ = $d_{11,12}$	

Table 5
Materials List, 13-30 MHz Log Periodic Dipole Array

	Material Description	*Quantity*
1)	Aluminum tubing—0.047″ wall thickness	
	1″—12′ or 6′ lengths	126 lineal feet
	7/8″—12′ lengths	96 lineal feet
	7/8″—6′ or 12′ lengths	66 lineal feet
	3/4″—8′ lengths	16 lineal feet
2)	Stainless-steel hose clamps—2″ max	48 ea
3)	Stainless-steel hose clamps—1 1/4″ max	26 ea
4)	TV type U bolts	14 ea
5)	U bolts, galv. type	
	5/16″ × 1 1/2″	4 ea
	1/4″ × 1″	2 ea
6)	1″ ID polyethylene water-service pipe—160 lb/in.² test, approx. 1 1/4″ OD	20 lineal feet
	A) 1 1/4″ × 1 1/4″ × 1/8″ aluminum angle—6′ lengths	30 lineal feet
	B) 1″ × 1/4″ aluminum bar—6′ lengths	12 lineal feet
7)	1 1/4″ top rail of chain-link fence	26 lineal feet
8)	1:1 toroid balun	1 ea
9)	6-32 × 1″ stainless steel screws	24 ea
	6-32 stainless steel nuts	48 ea
	No. 6 solder lugs	24 ea
10)	#12 copper feeder wire	60 lineal feet
11A)	12″ × 8″ × 1/4″ aluminum plate	1 ea
B)	6″ × 4″ × 1/4″ aluminum plate	1 ea
12A)	3/4″ galv. pipe	3 lineal feet
B)	1″ galv. pipe—mast	5 lineal feet
13)	Galv. guy wire	50 lineal feet
14)	1/4″ × 2″ turnbuckles	4 ea
15)	1/4″ × 1 1/2″ eye bolts	2 ea
16)	TV guy clamps and eye bolts	2 ea

Table 6
Element Material Requirements, 13-30 MHz LPDA

El No.	***1″ tubing*** *Lth*	*Qty*	***7/8″ tubing*** *Lth*	*Qty*	***3/4″ tubing*** *Lth*	*Qty*	***1 1/4″ angle*** *Lth*	***1″ bar*** *Lth*
1	6′	2	6′	2	8′	2	3′	1′
2	6′	2	12′	2	—	—	3′	1′
3	6′	2	12′	2	—	—	3′	1′
4	6′	2	8.5′	2	—	—	3′	1′
5	6′	2	7′	2	—	—	3′	1′
6	6′	2	6′	2	—	—	3′	1′
7	6′	2	5′	2	—	—	2′	1′
8	6′	2	3.5′	2	—	—	2′	1′
9	6′	2	2.5′	2	—	—	2′	1′
10	3′	2	5′	2	—	—	2′	1′
11	3′	2	4′	2	—	—	2′	1′
12	3′	2	4′	2	—	—	2′	1′

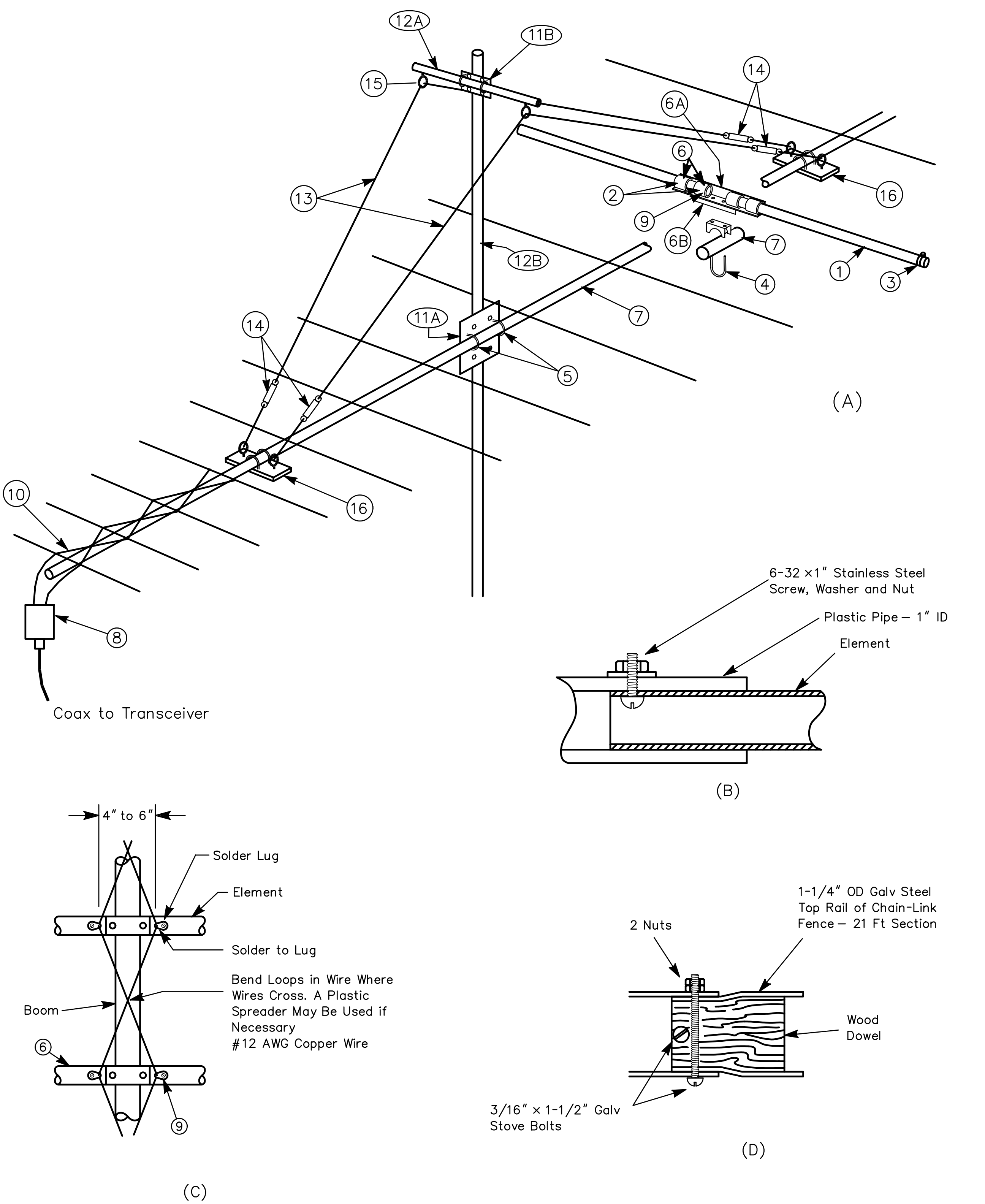

Fig 12—Construction diagram of the 13-30 MHz log periodic array. At B and C are shown the method of making electrical connection to each half element, and at D is shown how the boom sections are joined.

The Telerana

The Telerana (Spanish for "spider web") is a rotatable log periodic antenna that is lightweight, easy to construct and relatively inexpensive to build. Designed to cover 12.1 to 30 MHz, it was co-designed by George Smith, W4AEO, and Ansyl Eckols, YV5DLT, and first described by Eckols in *QST* for July 1981. Some of the design parameters are as follows.

1) $\tau = 0.9$
2) $\sigma = 0.05$
3) Gain = 6.7 dBi (4.6 dBd)
4) Feed arrangement: 400-Ω feeder line with 4:1 balun, fed with 52-Ω coax. The SWR is 1.5:1 or less in all amateur bands.

The array consists of 13 dipole elements, properly spaced and transposed, along an open-wire feeder having an impedance of approximately 400 Ω. See **Figs 13** and **14**. The array is fed at the forward (smallest) end with a 4:1 balun and RG-8 cable placed inside the front arm and leading to the transmitter. An alternative feed method is to use open wire or ordinary TV ribbon and a tuner, eliminating the balun.

The frame that supports the array (**Fig 15**) consists of four 15-foot fiberglass vaulting poles slipped over short nipples at the hub, appearing like wheel spokes (**Fig 16**). Instead of being mounted directly into the fiberglass, short metal tubing sleeves are inserted into the outer ends of the arm and the necessary holes are drilled to receive the wires and nylon.

A shopping list is provided in **Table 7**. The center hub is made from a 1¼-inch galvanized four-outlet cross or X and four 8-inch nipples (Fig 16). A 1-inch diameter X may be used alternatively, depending on the diameter of the fiberglass. A hole is drilled in the bottom of the hub to allow the cable to be passed through after welding the hub to the rotator mounting stub.

All four arms of the array must be 15 feet long. They should be strong and springy for maintaining the tautness of the array. If vaulting poles are used, try to obtain all of them with identical strength ratings.

The front spreader should be approximately 14.8 feet long. It can be much lighter than the four main arms, but must be strong enough to keep the lines rigid. If tapered, the spreader should have the same measurements from the center to each end. *Do not use metal for this spreader*.

Building the frame for the array is the first construction step. Once that is prepared, then everything else can be built onto it. Begin by assembling the hub and the four arms, letting them lie flat on the ground with the rotator stub inserted into a hole in the ground. The tip-to-tip length should be about 31.5 feet each way. A hose clamp is used at each end of the arms to prevent splitting. Insert the metal inserts at the outer ends of the arms, with 1 inch protruding. The mounting holes should have been drilled at this point. If the egg insulators and nylon cords are mounted to these tube inserts, the whole antenna can be disassembled simply by bending up the arms and pulling out the inserts with everything still attached.

Choose the arm to be at the front end. Mount two egg insulators at the front and rear to accommodate the inter-element feeder. These insulators should be as close as possible to the ends.

At each end of the cross-arm on top, install a small pulley and string nylon cord across and back. Tighten the cord until the upward bow reaches 3 feet above the hub. All cords will require retightening after the first few days because of stretching. The cross-arm can be laid on its side while preparing the feeder line. For the front-to-rear

Table 7
Shopping List for the Telerana

1—1¼-inch galvanized, 4-outlet cross or X.
4—8-inch nipples.
4—15-ft long arms. Vaulting poles suggested. These must be strong and all of the same strength (150 lb) or better.
1—Spreader, 14.8 ft long (must not be metal).
1—4:1 balun unless open-wire or TV cable is used.
12—Feed-line insulators made from Plexiglas or fiberglass.
36—Small egg insulators.
328 ft copper wire for elements; flexible 7/22 is suggested.
65.6 ft (20 m) #14 Copperweld wire for interelement feed line.
164 ft (50 m) strong ⅛-inch dia cord.
1—Roll of nylon monofilament fishing line, 50 lb test or better.
4—Metal tubing inserts go into the ends of the fiber glass arms.
2—Fiberglass fishing-rod blanks.
4—Hose clamps.

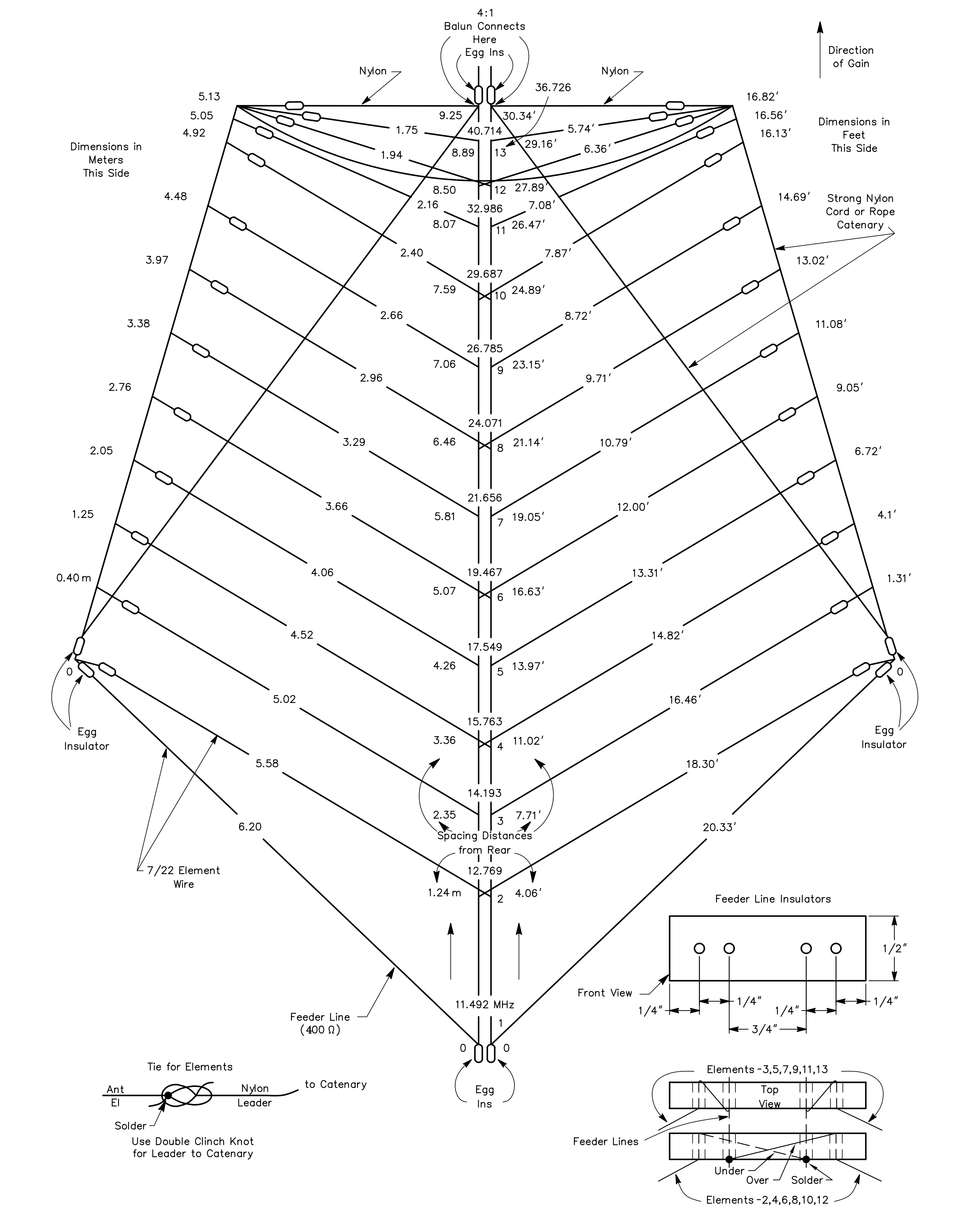

Fig 13—Configuration of the spider web antenna. Nylon monofilament line is used from the ends of the elements to the nylon cords. Solder all metal-to-metal connections. Use nylon line to tie every point where lines cross. The forward fiberglass feeder lies on the feeder line and is tied to it. Note that both metric and English measurements are shown except for the illustration of the feed-line insulator. Use soft-drawn copper or stranded wire for elements 2 through 12. Element 1 should have #7/22 flexible wire or #14 Copperweld.

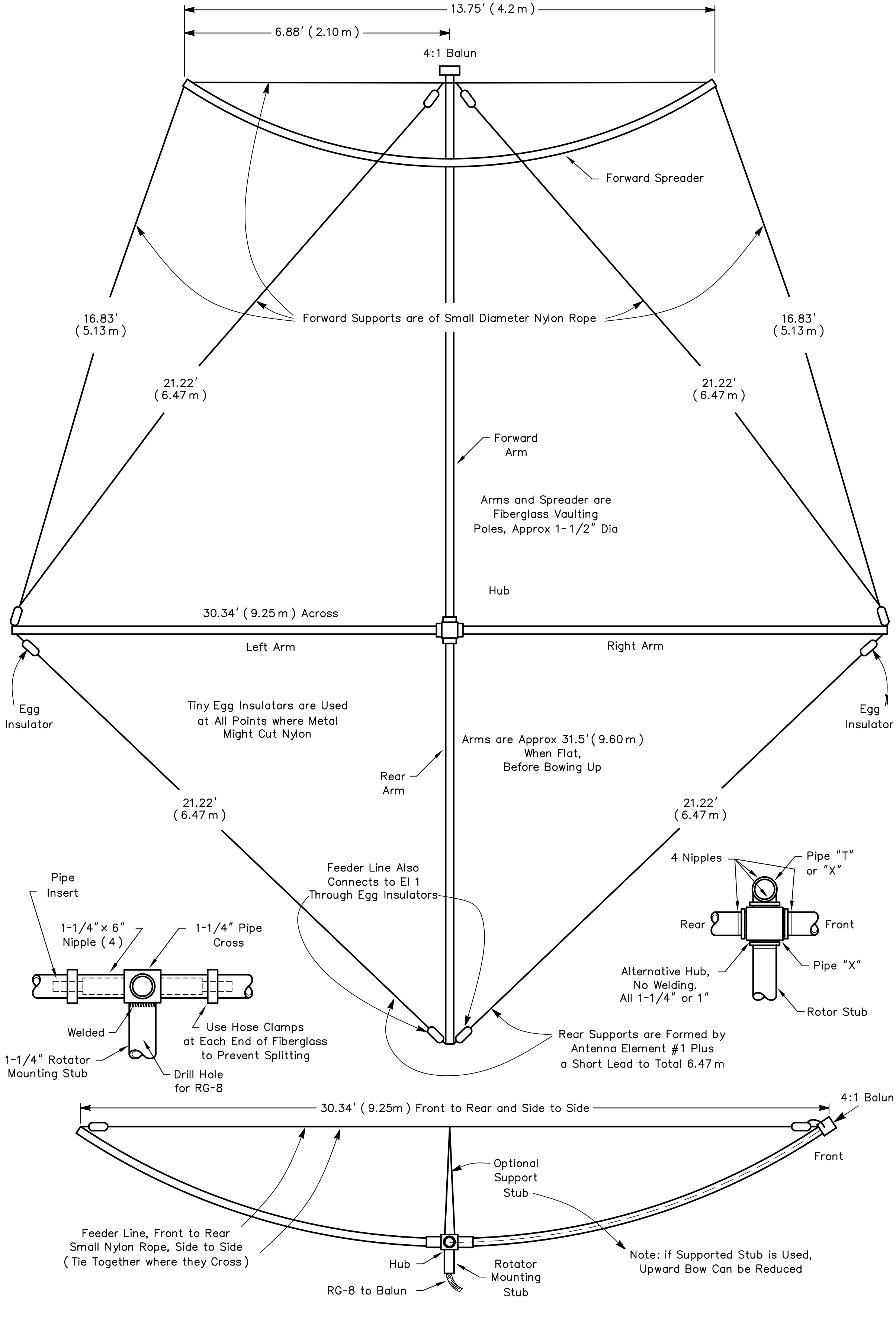

Fig 14—The frame construction for the spider web antenna. Two different hub arrangements are illustrated.

bowstring it is important to use a wire that will not stretch, such as #14 Copperweld. This bowstring is actually the inter-element transmission line. See **Fig 17**.

Secure the rear ends of the feeder to the two rear insulators, soldering the wrap. Before securing the fronts, slip the 12 insulators onto the two feed lines. A rope can be used temporarily to form the bow and to aid in mounting the feeder line. The end-to-end length of the feeder should be 30.24 feet.

Now lift both bows to their upright position and tie the feeder line and the cross-arm bowstring together where they cross, directly over and approximately 3 feet above the hub.

The next step is to install the no. 1 rear element from the rear egg insulators to the right and left cross-arms using other egg insulators to provide the proper element length. Be sure to solder the element halves to the transmission line. Complete this portion of the construction by installing the nylon cord catenaries from the front arm to the cross-arm tips. Use egg insulators where needed to prevent cutting the nylon cords.

In preparing the fiberglass front spreader, keep in mind that it should be 14.75 feet long before bowing and is approximately 13.75 feet when bowed. Secure the center of the bowstring to the end of the front arm. Lay the spreader on top of the feed line, then tie the feeder to the spreader with nylon fish line. String the catenary from the spreader tips to the cross-arm tips.

At this point of assembly, antenna elements 2 through 13 should be prepared. There will be two segments for each element. At the outer tip make a small loop and solder the wrap. This will be for the nylon leader. Measure the length plus 0.4 inch for wrapping and soldering the element segment to the feeder. Seven-strand #22 antenna wire is suggested for use here. Slide the feed-line insulators to their proper position and secure them temporarily.

The drawings show the necessary transposition scheme. Each element half of elements 1, 3, 5, 7, 9, 11 and 13 is connected to its own side of the feeder, while elements 2, 4, 6, 8, 10 and 12 cross over to the opposite side of the transmission line.

There are four holes in each of the transmission-line insulators (see Fig 13). The inner holes are for the transmission line, and the outer ones are for the elements. Since the array elements are slanted forward, they should pass through the insulator from front to back, then back over the insulator to the front side and be soldered to the transmission line. The small drawings of Fig 13 show the details of the element transpositions.

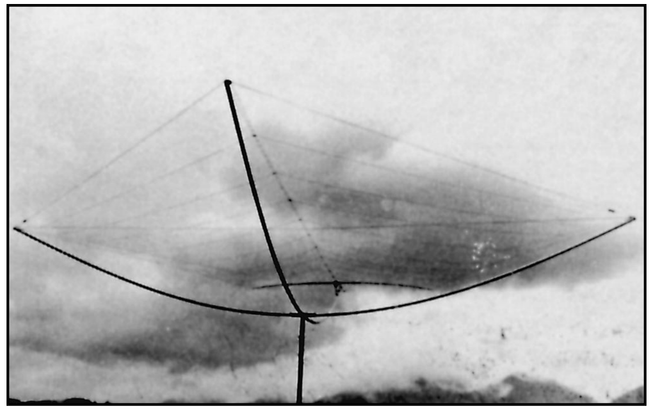

Fig 15—The spider web antenna, as shown in this somewhat deceptive photo, might bring to mind a rotatable clothesline. Of course it is much larger than a clothesline, as indicated by Figs 13 and 14. It can be lifted by hand.

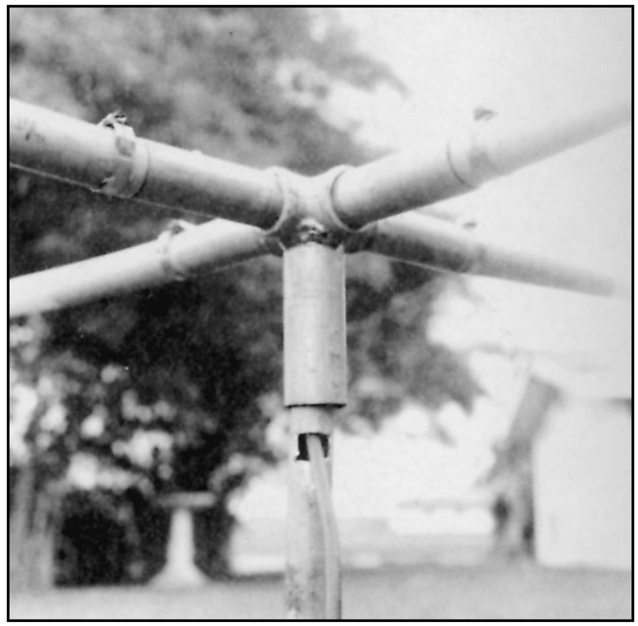

Fig 16—The simple arrangement of the hub of the spider web. See Fig 13 and the text for details.

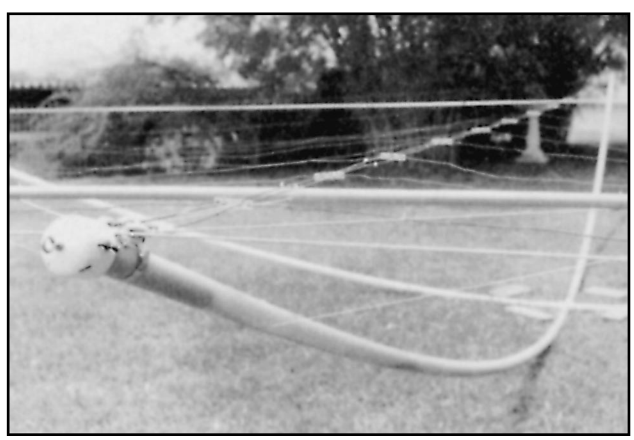

Fig 17—The elements, balun, transmission line and main bow of the spider web antenna.

Each place where lines cross, they are tied together with nylon line, whether copper/nylon or nylon/nylon. This makes the array much more rigid. All elements should be mounted loosely before you try to align the whole thing. Tightening any line or element affects all the others. There will be plenty of walking back and forth before the array is aligned properly. Do not expect it to be extremely taut.

The Pounder—A Single-Band 144-MHz LPDA

The 4-element Pounder LPDA pictured in **Fig 18** was developed by Jerry Hall, K1TD, for the 144-148 MHz band. Because it started as an experimental antenna, it utilizes some unusual construction techniques. However, it gives a very good account of itself, exhibiting a theoretical gain of 7.2 dBi and a front-to-back ratio of 20 dB or better. The Pounder is small and light. It weighs just 1 pound, and hence its name. In addition, as may be seen in **Fig 19**, it can be disassembled and reassembled quickly, making it an excellent antenna for portable use. This array also serves well as a fixed station antenna, and may be changed easily to either vertical or horizontal polarization.

The antenna feeder consists of two lengths of 1/2 × 1/2 × 1/16-inch angle aluminum. The feeder also serves as the boom for the Pounder. In the first experimental model the array contained only two elements with a spacing of 1 foot, so a boom length of 1 foot was the primary design requirement for the 4-element version. **Table 8** gives the design data for the 4-element array.

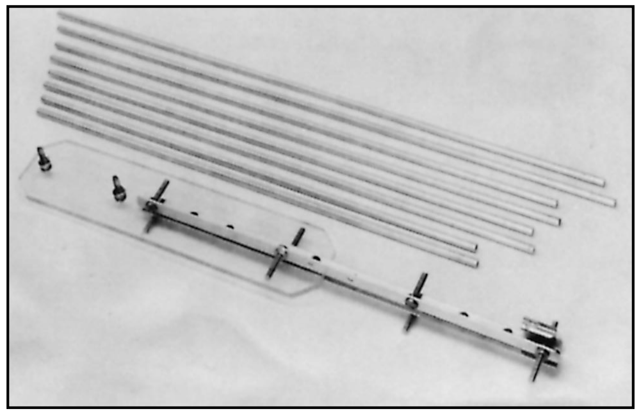

Fig 19—One end of each half element is tapped to fasten onto boom-mounted screws. Thus, disassembly of the array consists of merely unscrewing 8 half elements from the boom, and the entire array can be packaged in a small bundle of only 21 inches in length.

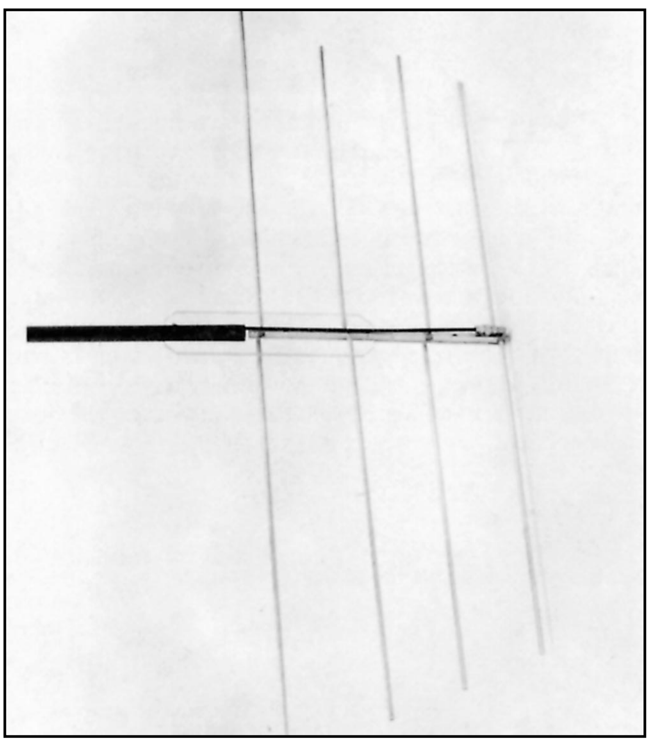

Fig 18—The 144-MHz Pounder. The boom extension running out of the picture is a 40-in. length of slotted PVC tubing, 7/8-in. OD. This tubing may be clamped to the side of a tower or attached to a mast with a small boom-to-mast plate. Rotating the tubing appropriately at the clamp will provide for either vertical or horizontal polarization.

Table 8

Design Parameters for the 144-MHz Pounder

$f1$ = 143 MHz
f_n = 148 MHz
B = 1.0350
τ = 0.92
σ = 0.053
Gain = 7.2 dBi = 5.1 dBd
cot α = 2.6500
B_{ar} = 1.2306
B_s = 1.2736
L = 0.98 ft
N = 3.90 elements (increase to 4)
Z_t = none
R_o = 52 Ω
Z_{av} = 312.8 Ω
σ' = 0.05526
Z_0 = 75.1 Ω
Antenna feeder:
1/2 × 1/2 × 1/16″ angle aluminum spaced 1/4”
Balun: 1:1 (see text)
Feed line: 52-Ω coax (see text)

Element lengths:
$\ell 1$ = 3.441 ft
$\ell 2$ = 3.165 ft
$\ell 3$ = 2.912 ft
$\ell 4$ = 2.679 ft
Element spacings:
d_{12} = 0.365 ft
d_{23} = 0.336 ft
d_{34} = 0.309 ft
Element diameters:
All = 0.25 in.
ℓ/diam ratios:
$\ell 4/diam_4$ = 128.6
$\ell 3/diam_3$ = 139.8
$\ell 2/diam_2$ = 151.9
$\ell 1/diam_1$ = 165.1

Construction

The general construction approach for the Pounder may be seen in the photographs. Drilled and tapped pieces of Plexiglas sheet, 1/4-inch thick, serve as insulating spacers for the angle aluminum feeder. Two spacers are used, one near the front and one near the rear of the array. Four no. 6-32 × 1/4-inch pan head screws secure each aluminum angle section to the Plexiglas spacers, **Figs 20** and **21**. Use flat washers with each screw to prevent it from touching the angle stock on the opposite side of the spacer. Be sure the screws are not so long as to short out the feeder! A clearance of about 1/16 inch has been found sufficient. If you have doubts about the screw lengths, check the assembled boom for a short with your ohmmeter on a megohms range.

Either of two mounting techniques may be used for the Pounder. As shown in Figs 18 and 19, the rear spacer measures 10 × 2 1/2 inches, with 45° corners to avoid sharp points. This spacer also accommodates a boom extension of PVC tubing, which is attached with two no. 10-32 × 1-inch screws. This tubing provides for side mounting the Pounder away from a mast or tower.

An alternative support arrangement is shown in Fig 20. Two 1/2 × 3-inch Plexiglas spacers are used at the front and rear of the array. Each spacer has four holes drilled 5/8 inch apart and tapped with no. 6-32 threads. Two screws enter each spacer from either side to make a tight aluminum-Plexiglas-aluminum sandwich. At the center of the boom, secured with only two screws, is a 2 × 18-inch strip of 1/4-inch Plexiglas. This strip is slotted about 2 inches from each end to accept hose clamps for mounting the Pounder atop a mast. As shown, the strip is attached for vertical polarization. Alternate mounting holes, visible on the now-horizontal lip of the angle stock, provide for horizontal polarization. Although sufficient, this mounting arrangement is not as sturdy as that shown in Fig 18.

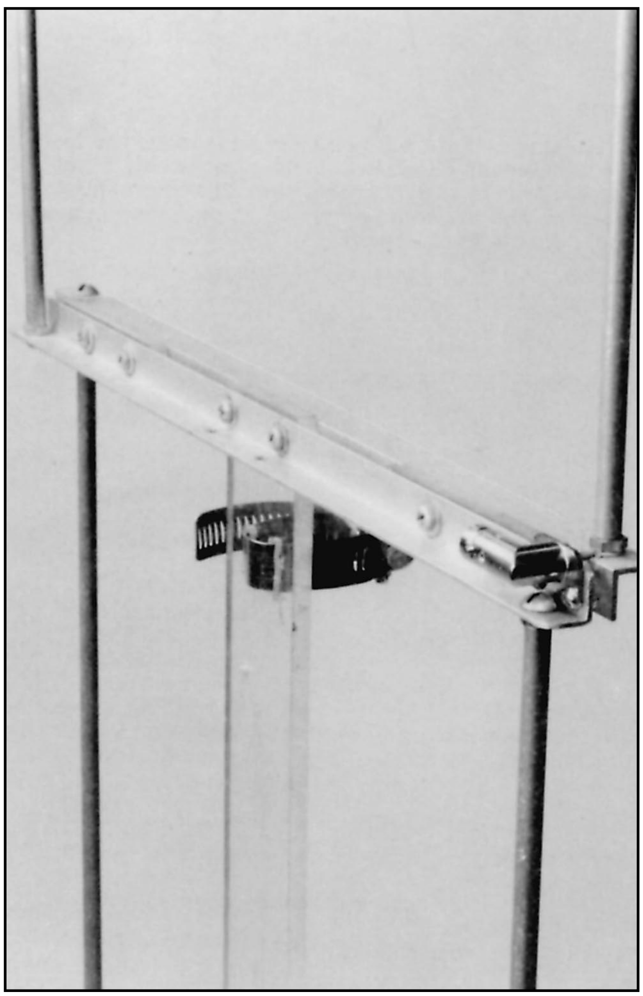

Fig 20—A close-up look at the boom, showing an alternative mounting scheme for the Pounder. This photo shows an earlier 2-element array, but the boom construction is unchanged with added elements. See text for details.

The elements are lengths of thick-wall aluminum tubing, 1/4-inch OD. The inside wall conveniently accepts a no. 10-32 tap. The threads should penetrate the tubing to a depth of at least 1 inch. Eight no. 10-32 × 1-inch screws are attached to the boom at the proper element spacings and held in place with no. 10-32 nuts, Fig 19. For assembly, the elements are then simply screwed into place.

Note that with this construction arrangement, the two halves of any individual element are not precisely collinear; their axes are offset by about 3/4 inch. This offset does not seem to affect performance.

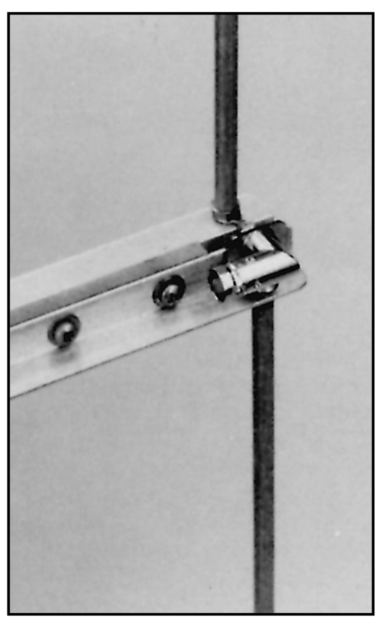

Fig 21—The feed arrangement. A right-angle chassis-mount BNC connector, modified by removing a portion of the flange, provides for ready connection of a coax feed line. A short length of bus wire connects the center pin to the opposite feeder conductor.

The Feed Arrangement

Use care in initially mounting and cutting the elements to length. To obtain the 180° crossover feed arrangement, the element halves from a single section of the feeder/boom must alternate directions. That is, the halves of elements 1 and 3 will point to one side, and of elements 2 and 4 to the other. This arrangement may be seen by observing the element mounting screws in Fig 19. Because of this mounting scheme, the length of tubing for an element "half" is not simply half of the length given in Table 8. After final assembly, halves for elements 2 and 4 will have a slight overlap, while elements 1 and 3 are extended somewhat by the boom thickness. The best procedure is to cut each assembled element to its final length by measuring from tip to tip.

The Pounder may be fed with RG-58 or RG-59 coax and a BNC connector. A modified right-angle chassis-mount BNC connector is attached to one side of the feeder/boom assembly for cable connection, Fig 21. The modification consists of cutting away part of the mounting flange that would otherwise protrude from the boom assembly. This leaves only two mounting-flange holes, but these are sufficient. A short length of small bus wire connects the center pin to the opposite side of the feeder, where it is secured under the mounting-screw nut for the shortest element.

For operation, the coax may be secured to the PVC boom extension or to the mast with electrical tape. It is also advisable to use a balun, especially if the Pounder is operated with vertical elements. A choke type of balun is satisfactory, formed by taping 6 turns of the coax into a coil of 3 inches diameter, but a bead balun is perferred (see Chapter 26). The balun should be placed at the point where the coax is brought away from the boom. If the mounting arrangement of Fig 20 is used with vertical polarization, a second balun should be located approximately $^{1}/_{4}$ wavelength down the coax line from the first. This will place it at about the level of the lower tips of the elements. For long runs of coax to the transmitter, a transition from RG-58 to RG-8 or from RG-59 to RG-9 is suggested, to reduce line losses. Make this transition at some convenient point near the array.

No shorting feeder termination is used with the array described here. In the basic theory section of this chapter, it is stated that direct feed of an LPDA is usually not possible with 52-Ω coax if a good match is to be obtained. The feeder Z_0 of this array is in the neighborhood of 120 Ω, and with this value, Eq 9 indicates R_0 to be 72.6 Ω. Thus, the theoretical mean SWR with 52-Ω line is 72.6/52 or 1.4 to 1. Upon array completion, the measured SWR (52-Ω line) was found to be relatively constant across the band, with a value of about 1.7 to 1. The Pounder offers a better match to 72-Ω coax.

Being an all-driven array, the Pounder is more immune to changes in feed-point impedance caused by nearby objects than is a parasitic array. This became obvious during portable use when the array was operated near trees and other objects . . . the SWR did not change noticeably with antenna rotation toward and away from those objects. This indicates the Pounder should behave well in a restricted environment, such as an attic. For weighing just one pound, this array indeed does give a good account of itself.

The Log Periodic V Array

The log periodic resonant V array is a modification of the LPDA, as shown in **Fig 22**. Dr Paul E. Mayes and Dr Robert L. Carrel published a report on the log periodic V array (LPVA) in the IRE Wescon Convention Record in 1961. (See the Bibliography listing at the end of this chapter.) At the antenna laboratory of the University of Illinois, they found that by simply tilting the elements toward the apex, the array could be operated in higher resonance modes with an increase in gain (9 to 13 dBd total gain), yielding a pattern with negligible side lobes. The information presented here is based on an October 1979 *QST* article by Peter D. Rhodes, K4EWG.

A higher resonance mode is defined as a frequency that is an odd multiple of the fundamental array frequency. For example, the higher resonance modes of 7 MHz are 21 MHz, 35 MHz, 49 MHz and so on. The fundamental mode is called the λ/2 (half-

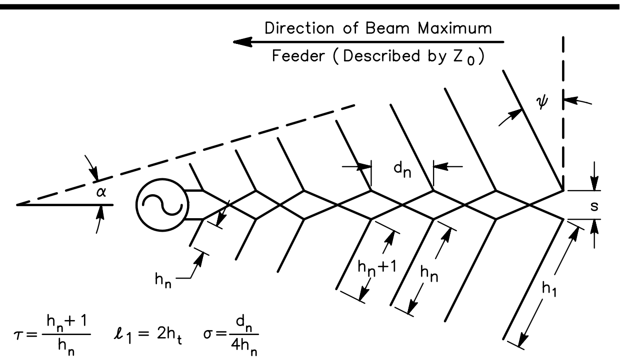

Fig 22—LPVA schematic diagram and definition of terms.

wavelength) mode, and each odd multiple as follows: 3λ/2, 5λ/2, 7λ/2, and so forth, to the (2n – 1)λ/2 mode.

The usefulness of such an array becomes obvious when one considers an LPVA with a fundamental frequency design of 7 to 14 MHz that can also operate in the 3λ/2 mode at 21 to 42 MHz. A six-band array can easily be developed to yield 7 dBd gain at 7, 10 and 14 MHz, and 10 dBd gain at 21, 24.9 and 28 MHz, without traps. Also, using proper design parameters, the same array can be employed in the 5λ/2 mode to cover the 35 to 70-MHz range.

A 7-30 MHz LPVA with minimum design parameters (fewest elements and shortest boom) is shown in **Fig 23**. This array was designed and built to test the LPVA theory under the most extreme minimum design parameters, and the results confirmed the theory.

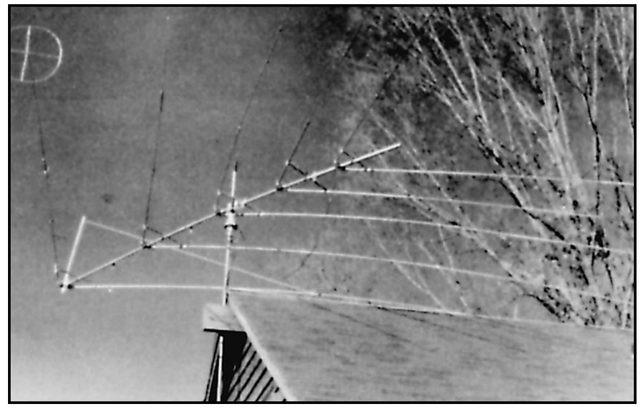

Fig 23—A pedestrian's view of the 5-element 7-30 MHz log periodic V array showing one of the capacitance hats on the rear element.

Theory of Operation

The basic concepts of the LPDA also apply to the LPV array. That is, a series of interconnected "cells" or elements are constructed so that each adjacent cell or element differs by the design or scaling factor, τ (**Fig 24**). If $\ell 1$ is the length of the longest element in the array and ℓ_n the length of the shortest, the relationship to adjacent elements is as follows:

$$\ell 1 = \frac{492}{f1} \qquad \text{(Eq 1)}$$

$\ell 2 = \tau \ell 1$

$\ell 3 = \tau \ell 2$

$\ell 4 = \tau \ell 3$, and so on, to

$$\ell_n = \tau \ell_{n-1} \qquad \text{(Eq 2)}$$

where

f1 = lowest desired frequency and

n = total number of elements

Assume d_{12} is the spacing between elements $\ell 1$ and $\ell 2$. Then d_{n-1} is the spacing between the last or shortest elements ℓ_{n-1} and ℓ_n, where n is equal to the total number of elements. The relationship to adjacent element spacings is as follows:

$d_{12} = {}^1/_2\,(\ell 1 - \ell 2) \cot \alpha$

$d_{23} = \tau d_{12}$

$d_{34} = \tau d_{23}$

$d_{45} = \tau d_{34}$

.

.

.

$$d_{n-1,n} = \tau d_{n-2,n-1} \qquad \text{(Eq 3)}$$

where

$\alpha = {}^1/_2$ the apex angle

$$\sigma = {}^1/_4(1 - \tau) \cot \alpha \qquad \text{(Eq 4)}$$

The above information is no different than was presented earlier in this chapter for the LPDA. It becomes obvious that the elements, cells of elements and their associated spacings, differ by the design parameter τ. Each band of frequencies between any f and τf corresponds to one period of the structure. In order to be frequency independent (or nearly so), the

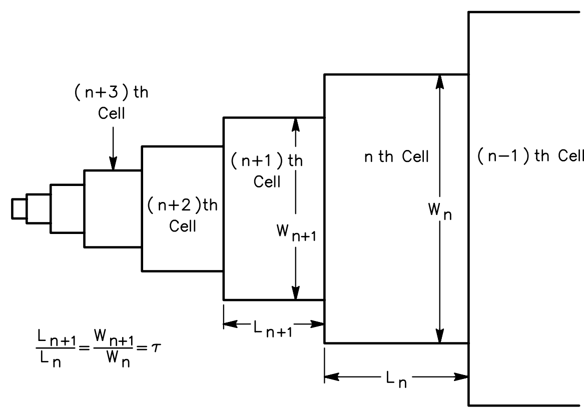

Fig 24—An interconnection of a geometric progression of cells.

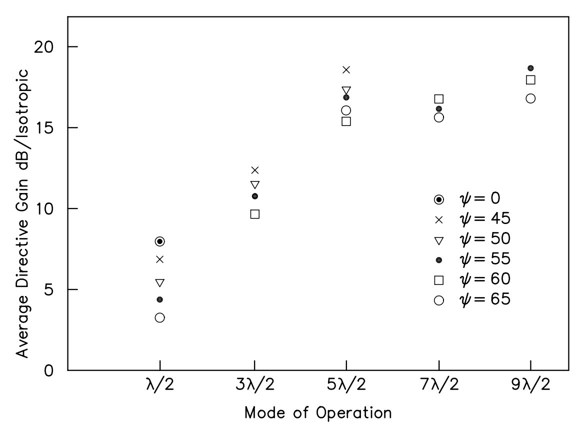

Fig 25—Average directive gain above isotropic (dBi). Subtract 2.1 from gain values to obtain gain above a dipole (dBd).

variation in performance (impedance, gain, front-to-back ratio, pattern, and so forth) across a frequency period must be negligible.

The active region is defined as the radiating portion or cell within the array which is being excited at a given frequency, f, within the array passband. As the frequency decreases, the active cell moves toward the longer elements, and as the frequency increases, the active cell moves toward the shorter elements. With variations of the design constant, τ, the apex half angle α (or relative spacing constant σ), and the element-to-element feeder spacing, S, the following trends are found:

1) The gain increases as τ increases (more elements for a given f) and α decreases (wider element spacing).

2) The average input impedance decreases with increasing α (smaller element spacing) and increasing τ (more elements for a given f).

3) The average input impedance decreases with decreasing S, and increasing conductor size of the element-to-element feeder.

As described earlier, the LPVA operates at higher order resonance points. That is, energy is readily accepted from the feeder by those elements which are near any of the odd-multiple resonances ($\lambda/2$, $3\lambda/2$, $5\lambda/2$, and so on). The higher order modes of the LPVA are higher order space harmonics (see Mayes, Deschamps and Patton Bibliography listing). Hence, when an LPVA is operated at a frequency whose half-wavelength is shorter than the smallest element, the energy on the feeder will propagate to the vicinity of the $3\lambda/2$ element and be radiated.

The elements are tilted toward the apex of the array by an angle, ψ, shown in Fig 22. The tilt angle, ψ, determines the radiation pattern and subsequent gain in the various modes. For each mode there is a different tilt angle that produces maximum gain. Mayes and Carrel did extensive experimental work with an LPVA of 25 elements with $\tau = 0.95$ and $\sigma = 0.0268$. The tilt angle, ψ, was varied from 0° to 65° and radiation patterns were plotted in the $\lambda/2$ through $7\lambda/2$ modes. Gain data are plotted in **Fig 25**. Operation in the higher modes is improved by increasing τ (more elements) and decreasing σ (closer element spacing).

When considering any single mode, the characteristic impedance is comparable with that of the LPDA; it is predominantly real and clustered around a central value, R_0. The central value, R_0, for each mode increases with Z_0 (feeder impedance). Thus, as with the LPDA, control of the LPVA input impedance can be accomplished by controlling Z_0.

When multimode operation is desired, a compromise must be made in order to determine a fixed impedance level. The multimode array impedance is defined as the weighted mean resistance level, R_{wm}. Also, it can be shown that R_{wm} lies between the R_0 central values of two adjacent modes. For example,

$$R_{0 1/2} < R_{wm} < R_{0 3/2} \quad \text{(Eq 5)}$$

where

$R_{0 1/2}$ = $\lambda/2$ mode impedance, center value

$R_{0 3/2}$ = $3\lambda/2$ mode impedance, center value

and where

$$R_0 = \sqrt{R_{max} \times R_{min}} \quad \text{(Eq 6)}$$

$$SWR = \sqrt{\frac{R_{max}}{R_{min}}} \quad \text{(Eq 7)}$$

The weighted mean resistance level between the $\lambda/2$ and $3\lambda/2$ modes is defined by

$$R_{wm} = \sqrt{R_{0 1/2} R_{0 1/2} \frac{SWR_{3/2}}{SWR_{1/2}}} \quad \text{(Eq 8)}$$

where

$SWR_{1/2}$ = SWR in $\lambda/2$ mode

$SWR_{3/2}$ = SWR in $3\lambda/2$ mode

Once Z_0 and ψ have been chosen, **Fig 26** can be used to estimate the R_{wm} value for a given LPVA. Notice the dominant role that Z_0 (feeder impedance) plays in the array impedance.

It is apparent from the preceding data that the LPVA is useful for covering a number of different bands spread over a wide range of the spectrum. It is fortunate that most of the amateur bands are harmonically related. By choosing a large design parameter, $\tau = 0.9$, a small relative spacing constant, $\sigma = 0.02$, and a tilt angle of $\psi = 40°$, an LPVA could easily cover the amateur bands from 7 through 54 MHz!

DESIGN PROCEDURE

A step-by-step design procedure for the log periodic V array follows.

1) Determine the operational bandwidth, B, in the λ/2 (fundamental) mode:

$$B = \frac{f_n}{f1} \quad \text{(Eq 9)}$$

where

f1 = lowest frequency, MHz
f_n = highest frequency, MHz

2) Determine τ for a desired number of elements, n, using **Fig 27**.

3) Determine element lengths $\ell 1$ to ℓ_n using Eqs 1 and 2 of this section.

4) Choose the highest operating mode desired and determine σ and ψ from **Fig 28**.

5) Determine cell boom length, L, from

$$L = \frac{2\sigma(\ell 1 - \ell_n)}{1 - \tau} \quad \text{(Eq 10)}$$

Note: If more than one LPVA cell is to be driven by a common feeder, the spacing between cells can be determined from

$$D_{12} = 2\sigma_1 \ell_{n1} \quad \text{(Eq 11)}$$

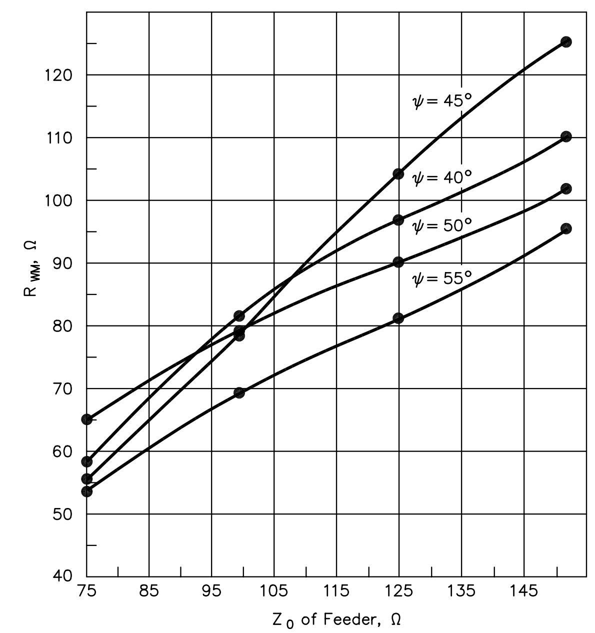

Fig 26—Weighted mean resistance level, R_{wm}, versus characteristic impedance of the feeder, Z_0, for various ψ angles.

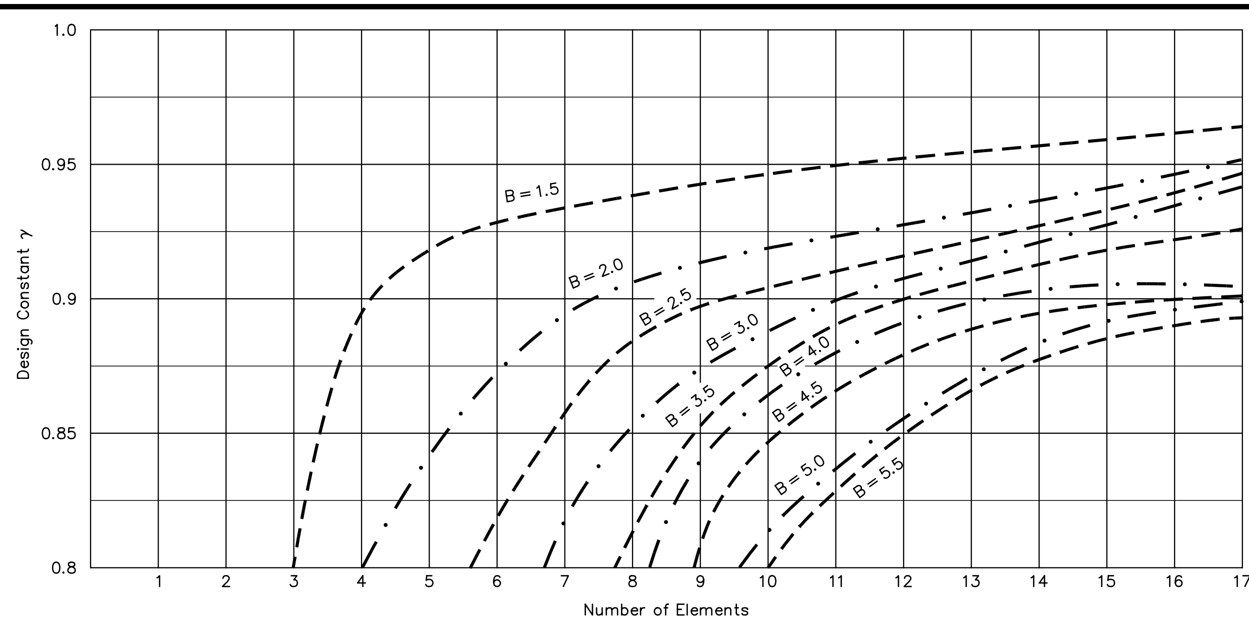

Fig 27—Design parameter, τ, versus number of elements, n, for various operational bandwidths, B.

where

D_{12} = element spacing between cell 1 (lower frequency cell) and cell 2 (higher frequency cell).

σ_1 = relative spacing constant for cell 1

ℓ_{n1} = shortest or last element within cell 1

6) Determine the mean resistance level, R_{wm}, using Fig 26.

7) Determine the element spacings using Eqs 3 and 4 of this section.

Construction Considerations

The 7-30 MHz LPVA shown in the photographs gives good results. The structural details can be seen in **Figs 29** and **30**, and additional data is presented in **Tables 1** and **2**. Although it performs well, it is likely that a more conservative design (two additional elements) would yield a narrower half-power (3 dB) beamwidth on 7 and 14 MHz.

It may be of interest to note that both linear and capacitive loading were used on ℓ1. The relationship in the next section may be used to estimate linear loading stub length and/or capacitance

Table 1
Design Dimensions for the LPVA

Element Lengths, ft	*Element Spacings, ft*	*Design Parameters*
ℓ1 = 56.22*	d_{12} = 9.15	τ = 0.8
ℓ2 = 56.22	d_{23} = 7.32	σ = 0.05
ℓ3 = 45.00	d_{34} = 5.86	α = 38.2°
ℓ4 = 36.00	d_{45} = 4.67	L = 27 ft**
ℓ5 = 28.79		ψ = 45°

*ℓ1 is a shortened element; the full-size dimension is 70.28 ft.

** The total physical boom length is L plus the distance to the ℓ5 cross bracing. The cross braces are 3 ft. long, and ψ = 45°; hence, the total boom length is 27 ft + 1.5 ft = 28.5 ft.

Table 2
Basic Materials for the LPVA

Elements	1½″, 6061-T6, 0.047″ wall aluminum tubing
Bracing	1¼″ × 1¼″ × ⅛″ aluminum angle
Boom	2½″ OD, 0.107″ wall aluminum tubing
U bolts	¼″ squared at loop to accommodate tilt angle ψ
Feeder	#12, solid copper wire
Cap. hat for ℓ1	#10 aluminum wire, 24″ diam
Linear loading for ℓ1	4′ loop, 3″ spacing each half of ℓ1

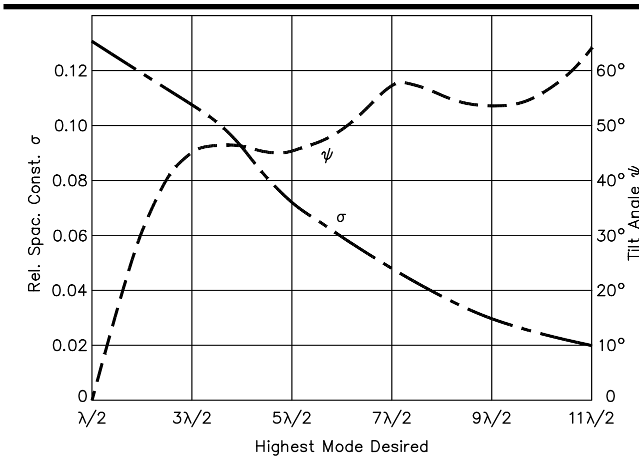

Fig 28—Optimum σ and ψ for an LPVA when the highest operating mode has been chosen.

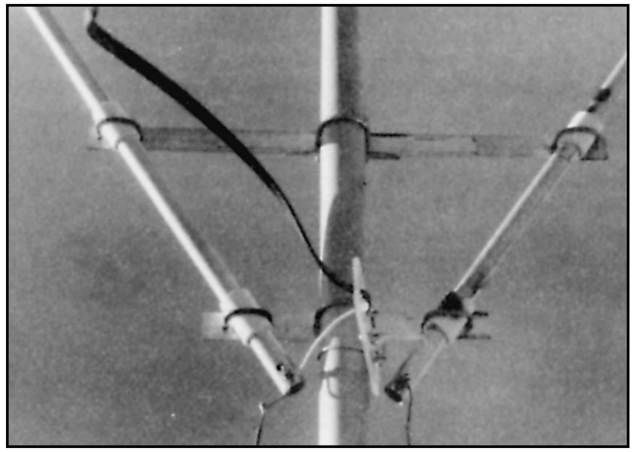

Fig 29—The element-to-boom detail is depicted here. Aluminum angle brackets, U bolts, and sections of PVC tubing are shown securing each element to the boom at two points. The 300-Ω twin-lead, threaded through a piece of polystyrene and attached to the foremost element, may be seen entering the picture at the top left. The end of the linear loading line for ℓ1 is visible near the bottom.

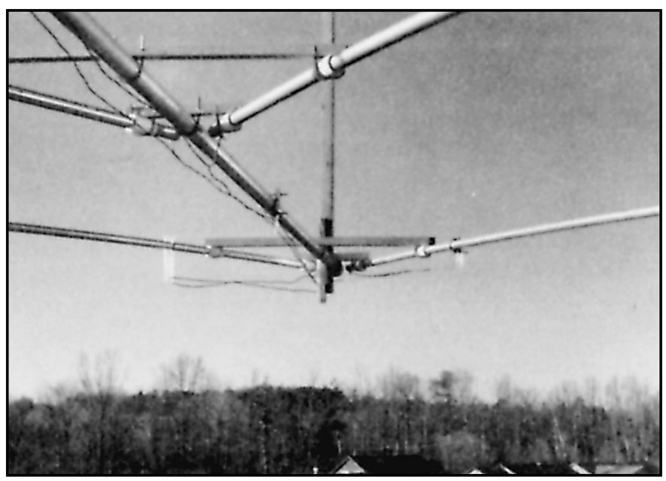

Fig 30—A shot of the rearmost elements looking at an angle to the boom. The linear loading line may be seen supported at various points along the boom and at the rear element by pieces of polystyrene.

hat size if construction constraints prohibit a full-sized array. However, performance in higher mode operations was less than optimum when shortened elements were used.

Linear Loading Stub Design

The following linear loading stub design equation may be used for approximating the stub length (one half of element, two stubs required).

$$L_s = \frac{2.734}{f} \arctan\left[\frac{33.9\left[\ln\frac{24h}{d} - 1\right]\left[1 - \left(\frac{fh}{234}\right)^2\right]}{fh \log\left(\frac{b}{a}\right)}\right] \quad \text{(Eq 12)}$$

where

L_s = linear loading stub length in feet required for each half element
h = element half length in feet
f = element resonant frequency in MHz
b = loading stub spacing in inches
a = *radius* (not diameter) of loading stub conductors in inches
d = average element diam in inches

Note: The resonant frequency, f, of an individual element of length, ℓ, can be found from:

$$f = \frac{468}{\ell} \quad \text{(Eq 13)}$$

The capacitance hat dimensions for each half element can be found from data in Chapter 2.

Log Periodic-Yagi Arrays

Several possibilities exist for constructing high-gain arrays that use the log periodic dipole as a basis. Tilting the elements toward the apex, for example, increases the gain by 3 to 5 dB on harmonic-resonance modes, as discussed in the previous section of this chapter. Another technique is to add parasitic elements to the LPDA to increase both the gain and the front-to-back ratio for a specific frequency within the passband. The LPDA-Yagi combination is simple in concept. It utilizes an LPDA group of driven elements, along with parasitic elements at normal Yagi spacings from the end elements of the LPDA.

The LPDA-Yagi combinations are endless. An example of a single-band high-gain design is a 2 or 3-element LPDA for 21.0 to 21.45 MHz with the addition of two or three parasitic directors and one parasitic reflector. The name Log-Yag array has been coined for these combination antennas. The LPDA portion of the array is of the usual design to cover the desired bandwidth, and standard Yagi design procedures are used for the parasitic elements. Information in this section is based on a December 1976 *QST* article by P. D. Rhodes, K4EWG, and J. R. Palmer, W4BBP, “The Log-Yag Array.”

THE LOG-YAG ARRAY

The Log-Yag array provides higher gain and greater directivity than would be realized with either the LPDA or Yagi array alone. The Yagi array requires a long boom and wide element spacing for wide bandwidth and high gain. This is because the Q of the Yagi system increases as the number of elements is increased and/or as the spacing between adjacent elements is decreased. An increase in the Q of the Yagi array means that the total bandwidth of that array is decreased, and optimum gain, front-to-back ratio and side-lobe rejection are obtainable only over small portions of the band.

The Log-Yag system overcomes this difficulty by using a multiple driven element "cell" designed in accordance with the principles of the log periodic dipole array. Since this log cell exhibits both gain and directivity by itself, it is a more effective radiator than a simple dipole driven element. The front-to-back ratio and gain of the log cell can be improved with the addition of a parasitic reflector and director.

It is not necessary for the parasitic element spacings to be large with respect to wavelength, as in the Yagi array, since the log cell is the determining factor in the array bandwidth. In fact, the element spacings within the log cell may be small with respect to a wavelength without appreciable deterioration of the cell gain. For example, decreasing the relative spacing constant (σ) from 0.1 to 0.05 will decrease the gain by less than 1 dB.

A Practical Example

The photographs and figures show a Log-Yag array for the 14-MHz amateur band. The array design takes the form of a 4-element log cell, a parasitic reflector spaced at 0.085 λ_{max}, and a parasitic director spaced at 0.15 λ_{max} (where λ_{max} is the longest free-space wavelength within the array passband). It has been found that array gain is almost unaffected with reflector spacings from 0.08 λ to 0.25 λ, and the increase in boom length is not justified. The function of the reflector is to improve the front-to-back ratio of the log cell while the director sharpens the forward lobe and decreases the half-power beamwidth. As the spacing between the parasitic elements and the log cell decreases, the parasitic elements must increase in length.

The log cell is designed to meet upper and lower band limits with σ = 0.05. The design parameter τ is dependent on the structure bandwidth, B_s. When the log periodic design parameters have been found, the element length and spacings can be determined.

Array layout and construction details can be seen in **Figs 31** through **34**. Characteristics of the array are given in **Table 1**.

The method of feeding the antenna is identical to that of feeding the log periodic dipole array without the parasitic elements. As shown in Fig 31, a balanced feeder is required for each log-cell element, and all adjacent elements are fed with a 180° phase shift by alternating connections. Since the Log-Yag array will be covering a relatively small bandwidth, the radiation resistance of the narrow-band log cell will vary from 80 to 90 Ω (tubing elements) depending on the operating bandwidth. The addition of para-

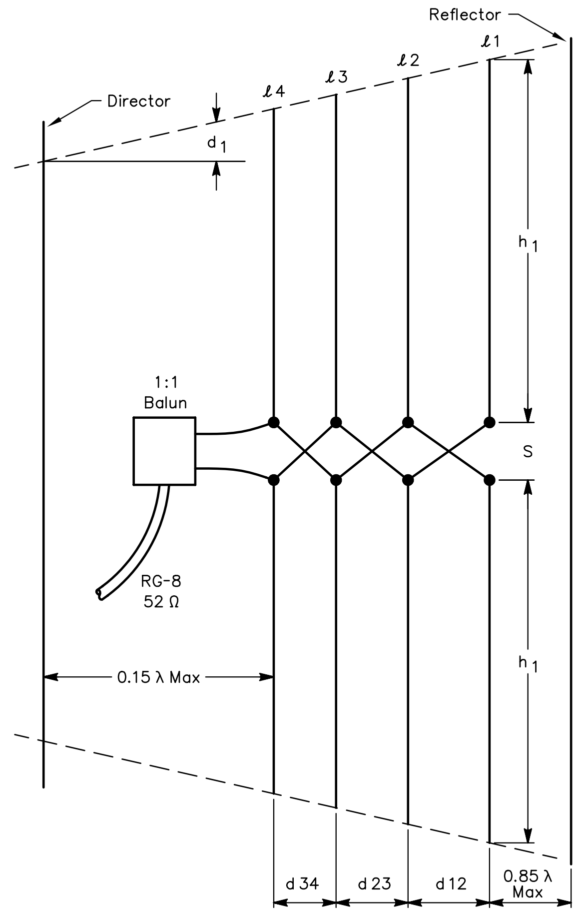

Fig 31—Layout of the Log-Yag array.

Table 1
Log-Yag Array Characteristics

1) Frequency range	14-14.35 MHz
2) Operating bandwidth	B = 1.025
3) Design parameter	τ = 0.946657
4) Apex half angle	α = 14.92°; cot α = 3.753
5) Half-power beam width	42° (14-14.35 MHz)
6) Bandwidth of structure	B_s = 1.17875
7) Free-space wavelength	l_{max} = 70.28 ft
8) Log-cell boom length	L = 10.0 ft
9) Longest log element	ℓ1 = 35.14 ft (a tabulation of element lengths and spacings is given in Table 2)
10) Forward gain (free space)	8.7 dBi
11) Front-to-back ratio	32 dB (theoretical)
12) Front-to-side ratio	45 dB (theoretical)
13) Input impedance	Z_0 = 37 Ω
14) SWR	1.3 to 1 (14-14.35 MHz)
15) Total weight	96 pounds
16) Wind-load area	8.5 sq ft
17) Feed-point impedance	Z_0 = 37 Ω
18) Reflector length	36.4 ft at 6.0 ft spacing
19) Director length	32.2 ft at 10.5 ft spacing
20) Total boom length	26.5 ft

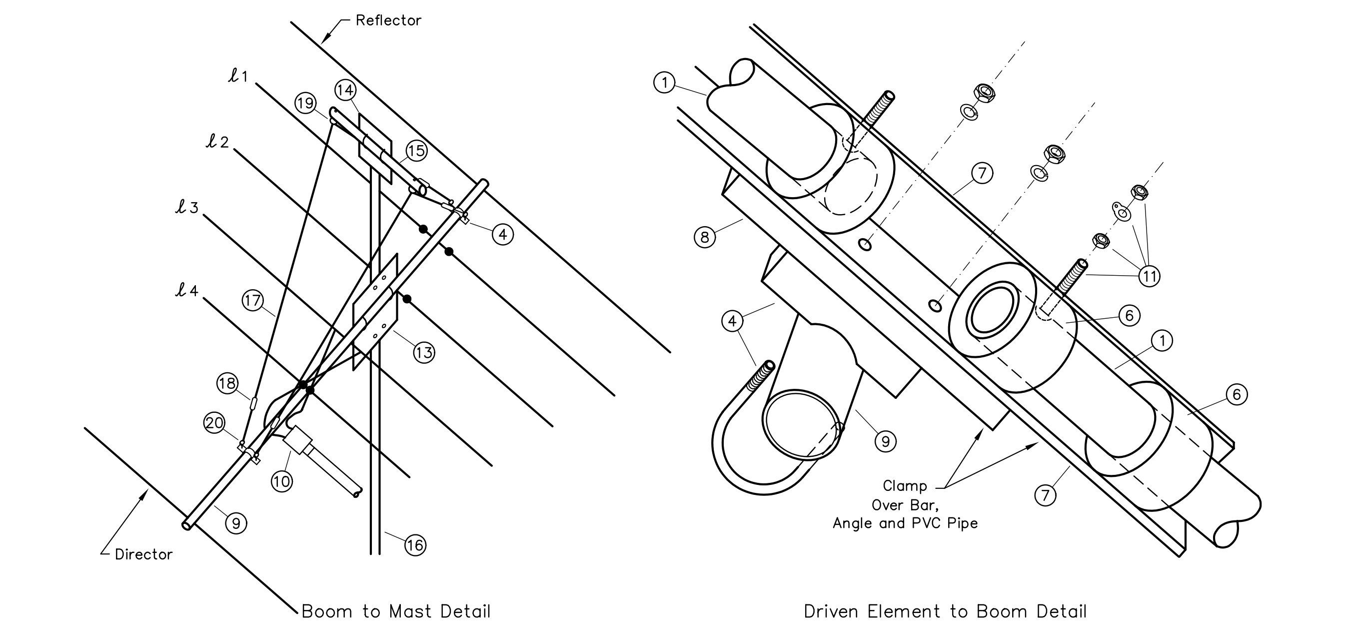

Fig 32—Assembly details. The numbered components refer to Table 4.

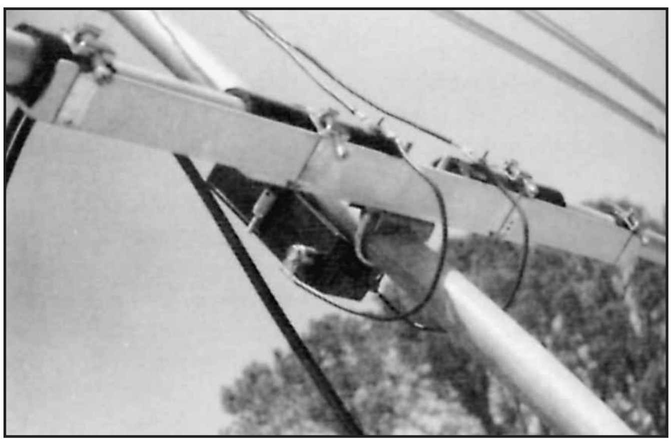

Fig 33—The attachment of the elements to the boom.

Table 2
Log-Yag Array Dimensions

Element	*Length Feet*	*Spacing Feet*
Reflector	36.40	6.00 (Ref. to ℓ1)
ℓ1	35.14	3.51 (d_{12})
ℓ2	33.27	3.32 (d_{23})
ℓ3	31.49	3.14 (d_{34})
ℓ4	29.81	10.57 (ℓ4 to dir)
Director	32.20	

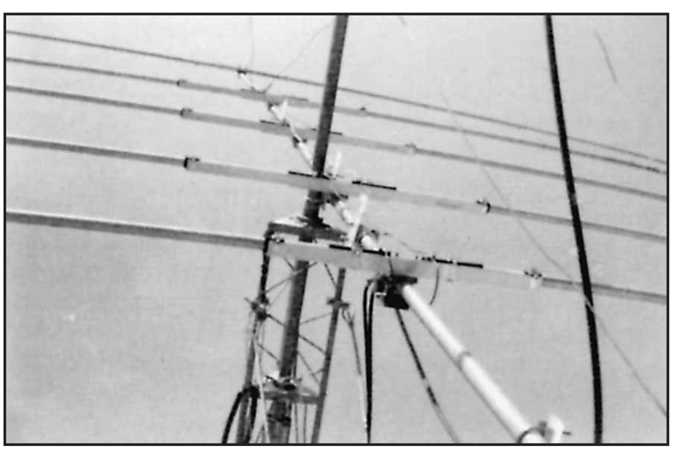

Fig 34—Looking from the front to the back of the Log-Yag array. A truss provides lateral and vertical support.

Table 3
Element Material Requirements, Log-Yag Array

	1-in. Tubing *Lth Ft*	*Qty*	***7/8-in. Tubing*** *Lth Ft*	*Qty*	***3/4-in. Tubing*** *Lth Ft*	*Qty*	***1/4-in. Angle*** *Lth Ft*	***1×1/4-in. Bar*** *Lth Ft*
Reflector	12	1	6	2	8	2	None	None
ℓ1	6	2	6	2	8	2	3	1
ℓ2	6	2	6	2	8	2	3	1
ℓ3	6	2	6	2	6	2	3	1
ℓ4	6	2	6	2	6	2	3	1
Director	12	1	6	2	6	2	None	None

sitic elements lowers the log-cell radiation resistance. Hence, it is recommended that a 1-to-1 balun be connected at the log-cell input terminals and 50-Ω coaxial cable be used for the feed line. The measured radiation resistance of the 14-MHz Log-Yag is 37 Ω, 14.0 to 14.35 MHz. It is assumed that tubing elements will be used. However, if a wire array is used then the radiation resistance, R_o, and antenna-feeder input impedance, Z_o, must be calculated so that the proper balun and coax may be used. The procedure is outlined in detail in the early part of this chapter.

Table 2 has array dimensions. **Tables 3** and **4** contain lists of the materials necessary to build the Log-Yag array.

Table 4
Materials List, Log-Yag Array

1) Aluminum tubing—0.047 in. wall thickness
   1 in.—12 ft lengths, 24 lin. ft.
   1 in.—12 ft or 6 ft lengths, 48 lin. ft
   7/8 in.—12 ft or 6 ft lengths, 72 lin. ft
   3/4 in.—8 ft lengths, 48 lin. ft
   3/4 in.—6 ft lengths, 36 lin. ft
2) Stainless steel hose clamps—2 in. max, 8 ea
3) Stainless steel hose clamps—1 1/4 in. max, 24 ea
4) TV-type U bolts—1 1/2 in., 6 ea
5) U bolts, galv. type: 5/16 in. × 1 1/2 in., 6 ea
5A) U bolts, galv. type: 1/4 in. × 1 in., 2 ea
6) 1 in. ID water-service polyethylene pipe 160 lb/in.^{2} test, approx. 1 3/8 in. OD 7 lin. ft
7) 1 1/4 in. × 1 1/4 in. × 1/8 in. aluminum angle—6 ft lengths, 12 lin. ft
8) 1 in. × 1/4 in. aluminum bar—6 ft lengths, 6 lin. ft
9) 1 1/4 in. top rail of chain-link fence, 26.5 lin. ft
10) 1:1 toroid balun, 1 ea
11) No. 6-32 × 1 in. stainless steel screws, 8 ea
    No. 6-32 stainless steel nuts, 16 ea
    No. 6 solder lugs, 8 ea
12) No. 12 copper feed wire, 22 lin. ft
13) 12 in. × 6 in. × 1/4 in. aluminum plate, 1 ea
14) 6 in. × 4 in. × 1/4 in. aluminum plate, 1 ea
15) 3/4 in. galv. pipe, 3 lin. ft
16) 1 in. galv. pipe—mast, 5 lin. ft
17) Galv. guy wire, 50 lin. ft
18) 1/4 in. × 2 in. turnbuckles, 4 ea
19) 1/4 in. × 1 1/2 in. eye bolts, 2 ea
20) TV guy clamps and eyebolts, 2 ea

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